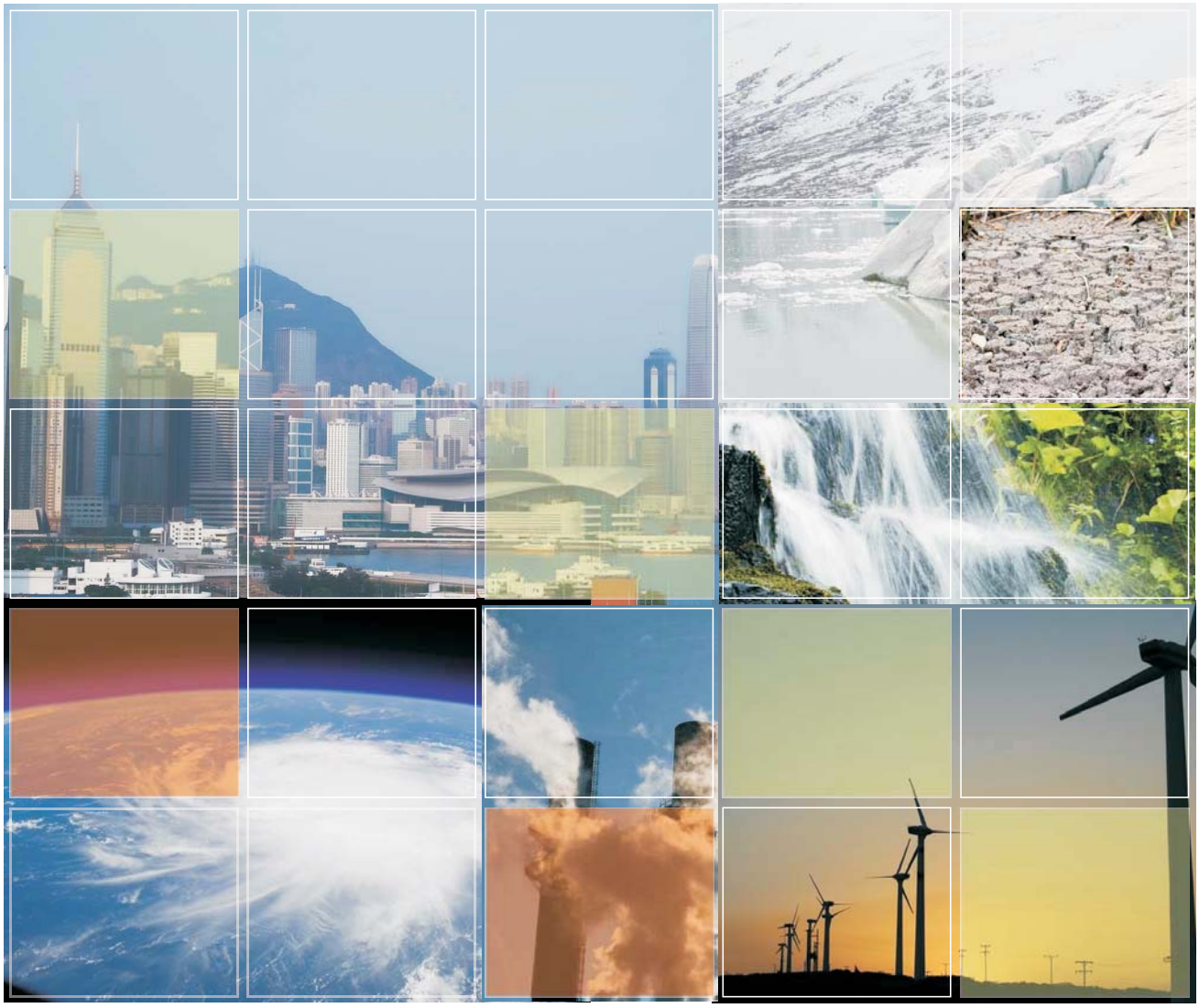
FINAL REPORT



Environmental Protection Department
The Government of the Hong Kong
Special Administrative Region

Agreement No. CE 45/2007 (EP)
A Study of Climate Change in Hong Kong - Feasibility Study

December 2010

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December 2010

Reference 0082487

For and on behalf of
ERM-Hong Kong, Limited

Approved by: Dr Andrew Jackson

Signed:

Position: Managing Director

Date: 3 December 2010

CONTENTS

APPENDICES

1 OVERVIEW

1.1 BACKGROUND

Climate change is a global phenomenon around which there is a broad consensus that international action is needed to prevent a material risk to society and, in particular, future generations.

The United Nations Framework Convention on Climate Change (hereafter referred to as "the Convention" or UNFCCC) is an overall framework for intergovernmental efforts to tackle the challenges posed by climate change and entered into force in March 1994. The Kyoto Protocol (the Protocol) is an international agreement linked to the Convention. The Protocol commits industralised countries (Annex I parties) to stabilize greenhouse gas (GHG) emissions under the principle of "common but differentiated responsibilities". The Protocol was adopted in December 1997, entered into force in February 2005 and has been ratified by 188 Parties to date.

Mainland China is a Party to the Convention and the Protocol. Under the Convention and the Protocol, and China as a non-Annex I Party is required to fulfill the following obligations -

- gathering and sharing information on GHG emissions, national policies and best practices;
- launching national strategies for addressing GHG emissions and adapting to expected impacts; and
- co-operating in preparing for adaptation to the impacts of climate change.

Following consultation with the Administration, the Central People's Government (CPG) notified the United Nations that the Convention and the Protocol were extended to the Hong Kong Special Administrative Region (SAR) with effect from May 2003. In the 2008/09 Policy Address, the Hong Kong SAR committed to making early preparations to meet the challenges of climate change through enhancing energy efficiency, using clean fuels, relying less on fossil fuels and promoting a low carbon economy. Following the announcement of a voluntary national target to reduce carbon intensity by the CPG in November 2009, the SAR Government is actively considering the adoption of a more aggressive target for reducing energy-related carbon intensity by 2020 and beyond.

1.2 OBJECTIVES

This study aims to provide the basis for additional strategies and measures for addressing climate change in Hong Kong, as well as necessary information to contribute to the CPG's national level communication under the UNFCCC.

Individual objectives of the study are summarised as follows-

- review and update the **inventories** of GHG emissions and removals and project future trends (*Section 2*).

- Evaluate existing and recommend additional policies and measures to reduce GHG, emissions or increase sinks of GHG, and assess their cost-effectiveness, economic, social and environmental implications of such **mitigation** measures (*Section 3*).

- Characterise the **impacts** of climate change in Hong Kong, and evaluate existing and recommend additional strategies and measures to facilitate adequate **adaptation** to climate change (*Section 4*).

- Evaluate existing and recommend further strategies and measures to promote the development and application of environmentally sound technologies and scientific research pertinent to, and public **awareness** of, climate change (*Section 5*).

The analyses summarised in the main body of this report is supported by a set of appendices that provide further information, as follows:

- *Appendix A: GHG Emissions Inventory.* This appendix provides further information on the methodologies used for the preparation of the inventory and the results for the period 1990 to 2006.

- *Appendix B: Mitigation Assessment.* This appendix documents the forecasted emissions for the period 2005 to 2030, the potential options for reducing emissions and the analysis of three alternate scenarios for emissions reduction.

- *Appendix C: Vulnerability and Adaptation Assessment.* This appendix summarises the findings of an assessment of the Hong Kong SAR's vulnerability to future climate change and the means of adapting to such change.

2 GREENHOUSE GAS EMISSIONS

2.1 INTRODUCTION

The Kyoto Protocol to the UNFCCC requires Non-Annex I parties which have ratified the Protocol to communicate a national (1) inventory of GHG emissions as part of their national communication. The Hong Kong SAR, as part of China which has ratified the Kyoto Protocol, is therefore also required to prepare a GHG inventory. This inventory will form part of China's inventory in its national communication which is to be submitted to the Conference of Parties (COP).

The inventory has been developed using internationally agreed and adopted methods, i.e. the *Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories*. The Guidelines include provision for the estimation of both sources of GHG emissions to the atmosphere and sinks, whereby GHGs are removed.

Different GHGs have differing impacts and Global Warming Potential (GWP) values are used to quantify the impact of GHG emissions in accordance with the IPCC Guidelines. The GWP is a measure of a particular GHG's contribution to global warming. The scale is a ratio of the contribution of global warming relative to that of the similar mass of carbon dioxide (which has a GWP of one). This approach is adopted internationally and allows the expression of all GHG emissions as carbon dioxide equivalents (CO_2-e).

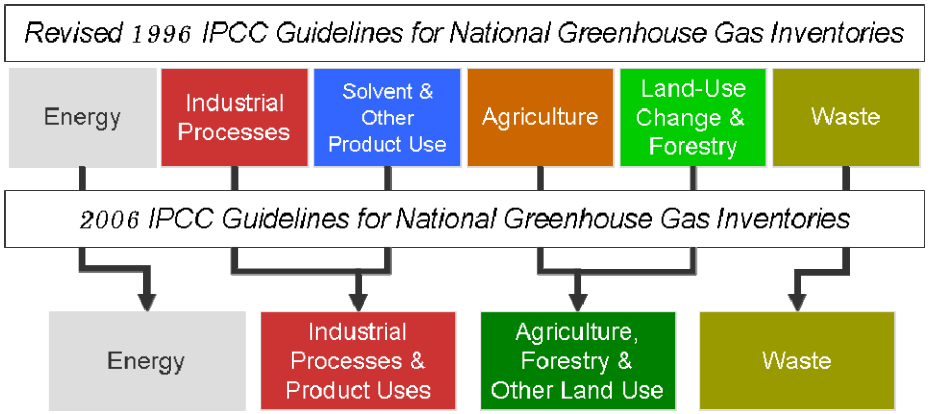
2.2 OVERVIEW OF ASSESSMENT METHODOLOGY

2.2.1 *Adoption of International Guidelines*

The estimation of emissions in this document follows the approach agreed internationally, including methods prescribed in the IPCC Guidelines. In particular, methods in the *2006 IPCC Guidelines* were employed to replace the corresponding methods in the revised *1996 IPCC Guidelines* as far as possible.

(1) For the sake of clarity in this report "national inventory" is used to refer to the inventory for China as a whole (ie including the HKSAR). "Domestic inventory" refers to the HKSAR inventory only.

Figure 2.1 ***Differences in Categorisation of Sources and Sinks between the 2006 and Revised 1996 IPCC Guidelines***



Note: "Other" category not shown for both sets of Guidelines.

The Energy and Waste sectors remain as independent sectors under the *2006 IPCC Guidelines*; however, Industrial Processes and Solvent & Other Product Use are combined as Industrial Processes & Product Uses (IPPU) and Agriculture and Land-use Change & Forestry are combined as Agriculture, Forestry & Other Land Use (AFOLU) under the *2006 IPCC Guidelines*. Categorisation of sources and sinks also differs between the two versions of the *Guidelines* at the more disaggregated level.

2.2.2 *Calculation Methods*

Emissions and Removals

The estimation of emissions from a particular source combines information on the extent to which a human activity takes place, referred to as *Activity Data* (AD), with coefficients quantifying the emissions or removals per unit activity, referred to as *Emission Factors* (EF).

The basic equation for estimating GHG emissions (or removals) is, therefore:

$$Emissions\ (Removals) = AD \bullet EF$$

In addition to activity data and emission factors, this basic equation can incorporate other estimation parameters to reflect actual emissions or removals (1). A number of other approaches are also provided to reflect the characteristics of certain processes that emit or remove GHGs (2). For example, stock change methods are used in the AFOLU sector, estimating CO_2 emissions from changes in the carbon content of living biomass and dead organic matter pools over time.

(1) IPCC, 2006, "IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1: General Guidance and Reporting"

(2) The method for GHG emission estimation, in IPCC 2006 Guidelines, is categorised into 3 levels according to the level of methodological complexity or *tier*. Tier 1 is the basic method, Tier 2 intermediate, and Tier 3 most demanding in terms of complexity and data requirement. Tiers 2 and 3 are sometimes referred to as higher *tier* methods and are generally considered to be more accurate.

Global Warming Potential of GHGs

According to the IPCC Guidelines, the GWP is a measure of a particular GHG's contribution to global warming. The scale is a ratio of the contribution of global warming relative to that of the similar mass of carbon dioxide (which has a GWP of one), thus allowing the expression of all GHG emissions as carbon dioxide equivalents. A comparison of the GWPs adopted in the *Revised IPCC 1996 Guidelines* and the *2006 IPCC Guidelines* is shown in the *Table 2.1*.

Table 2.1 Comparison of 100-year GWP Estimates from the IPCC Guidelines

Gas	1996 IPCC GWP	2006 IPCC GWP
Carbon Dioxide	1	1
Methane	21	23
Nitrous Oxide	310	296
HFC-23	11,700	12,000
HFC-125	2,800	3,400
HFC-134a	1,300	1,300
HFC-143a	3,800	4,300
HFC-152a	140	120
HFC-227ea	2,900	3,500
HFC-236fa	6,300	9,400
Perfluoromethane (CF_4)	6,500	5,700
Perfluoroethane (C_2F_6)	9,200	11,900
Sulfur Hexafluoride (SF_6)	23,900	22,200

The GWPs presented in the *Revised 1996 IPCC Guidelines* were based on the findings of the *IPCC Second Assessment Report*, published in 1995 (IPCC, 1995) (1). The *2006 IPCC Guidelines* were updated according to the findings of the *IPCC Third Assessment Report* (IPCC, 2001). A *Fourth Assessment Report* (IPCC, 2007) (2) was released, in 2007, which further updated the GWPs. Under the Kyoto Protocol, the Conference of the Parties decided that the GWPs calculated in the *Second Assessment Report* are to be used for converting GHG emissions into carbon dioxide equivalents, and the later findings should not be applied until the end of 2012. This is further validated by the UNFCCC Guidelines. Therefore, for the purpose of this inventory compilation, the GWPs defined in the *Revised 1996 IPCC Guidelines* will be used.

2.3 EMISSIONS ESTIMATES, 1990 TO 2006

This section provides an overview of the inventory of GHG emissions. The overview is presented in two stages, firstly by total GHG emissions (expressed as Gg $CO_{2\text{-}e}$), followed by a more detailed analysis of GHG emissions by gas and sector.

(1) Climate Change 1995: The Physical Science Basis, Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

(2) Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

2.3.1 Total GHG Emissions

Table 2.2 summarises GHG emissions over the period 1990 to 2006, the emissions of $CO_{2\text{-}e}$ have risen from 35.3 million tonnes in 1990 to 42.3 million tonnes in 2006 (without Sector 3B) [1] . The Energy sector is the main contributor of GHG emissions, dominating the other three sectors. It is evident that emissions from electricity generation (accounting for about 57 to 67% of the total) and transport (about 16 to 23% of the total) are the most influential. Indeed, emissions from electricity generation generally were on the increase over the period, with the exception of a marked drop between 1993 and 1994 due to the introduction of low-carbon nuclear energy imports from Mainland China, in place of local generation by coal-fired power plants.

The Waste sector is the next most significant. The annual average share of GHG emissions from the Energy and Waste sectors from 1990 to 2006 was 93.0% and 4.5%, respectively. The IPPU and AFOLU sectors on average each contribute 2.2% and less than 1%, respectively. *Figure 2.2* and *Figure 2.3* show the trends in emissions by sector and gas type from 1990 to 2006.

(1) Sector 3B (Landuse) is excluded to be consistent with the UNFCCC GHG data reporting format.

Table 2.2 Detailed Breakdown of HK GHG Emissions by Concerned Sub-sector and its Percentage Share, from 1990 to 2006

Year	HK GHG Emissions by Sectors (kilotonnes CO_2-e)[a]							Percentage Share of HK GHG by Sectors (%)						
	Electricity Generation[b]	Transport	Other End Use of Fuel [c]	Waste	Industrial Process and Product Use	Agriculture, Forestry, Other Land Use (without 3B)	Total	Electricity Generation[b]	Transport	Other End Use of Fuel [c]	Waste	Industrial Process and Product Use	Agriculture, Forestry, Other Land Use (without 3B)	Total
1990	22,900	5,940	4,620	1,550	215	141	35,300	64.7%	16.8%	13.1%	4.4%	0.6%	0.4%	100%
1991	25,600	6,470	4,360	1,600	638	123	38,800	66.0%	16.7%	11.2%	4.1%	1.6%	0.3%	100%
1992	29,200	6,870	4,500	1,660	651	100	43,000	68.0%	16.0%	10.5%	3.8%	1.5%	0.2%	100%
1993	29,700	6,970	4,200	1,750	724	87	43,400	68.4%	16.1%	9.7%	4.0%	1.7%	0.2%	100%
1994	21,900	7,270	4,030	1,770	830	77	35,900	61.1%	20.2%	11.2%	4.9%	2.3%	0.2%	100%
1995	23,000	7,180	3,810	1,940	935	85	36,900	62.2%	19.5%	10.3%	5.3%	2.5%	0.2%	100%
1996	21,800	7,170	3,680	1,900	952	86	35,500	61.2%	20.2%	10.3%	5.3%	2.7%	0.2%	100%
1997	20,000	7,340	3,590	2,000	1,060	75	34,100	58.7%	21.5%	10.5%	5.9%	3.1%	0.2%	100%
1998	22,100	7,430	3,330	1,550	977	70	35,500	62.4%	20.9%	9.4%	4.4%	2.8%	0.2%	100%
1999	20,100	7,570	3,470	1,120	1,020	85	33,300	60.2%	22.7%	10.4%	3.4%	3.1%	0.3%	100%
2000	21,200	7,800	3,450	1,110	977	78	34,600	61.2%	22.5%	10.0%	3.2%	2.8%	0.2%	100%
2001	21,600	7,640	3,220	1,250	862	85	34,700	62.3%	22.0%	9.3%	3.6%	2.5%	0.2%	100%
2002	23,400	7,890	2,800	1,490	503	82	36,200	64.8%	21.8%	7.7%	4.1%	1.4%	0.2%	100%
2003	26,500	7,810	2,830	1,800	538	74	39,600	67.0%	19.7%	7.1%	4.5%	1.4%	0.2%	100%
2004	26,400	7,640	3,060	1,990	636	67	39,800	66.3%	19.2%	7.7%	5.0%	1.6%	0.2%	100%
2005	28,600	7,480	2,770	2,220	867	74	42,000	68.1%	17.8%	6.6%	5.3%	2.1%	0.2%	100%
2006	28,500	7,480	2,730	2,140	1,380	74	42,300	67.4%	17.7%	6.5%	5.1%	3.3%	0.2%	100%

Notes:

(a) 1 kilotonne CO_2-e in this table is equivalent to 1 Gg CO_2-e.

(b) Including towngas production – accounts for about 1% of GHG emissions as in the energy production sector

(c) Other End Use of Fuel covers manufacturing of solid fuels and other energy industries, manufacturing industries and construction, fugitive emissions from fuels and other minor sectors.

Figure 2.2 Total HK GHG Emissions from 1990 to 2006, by Sector

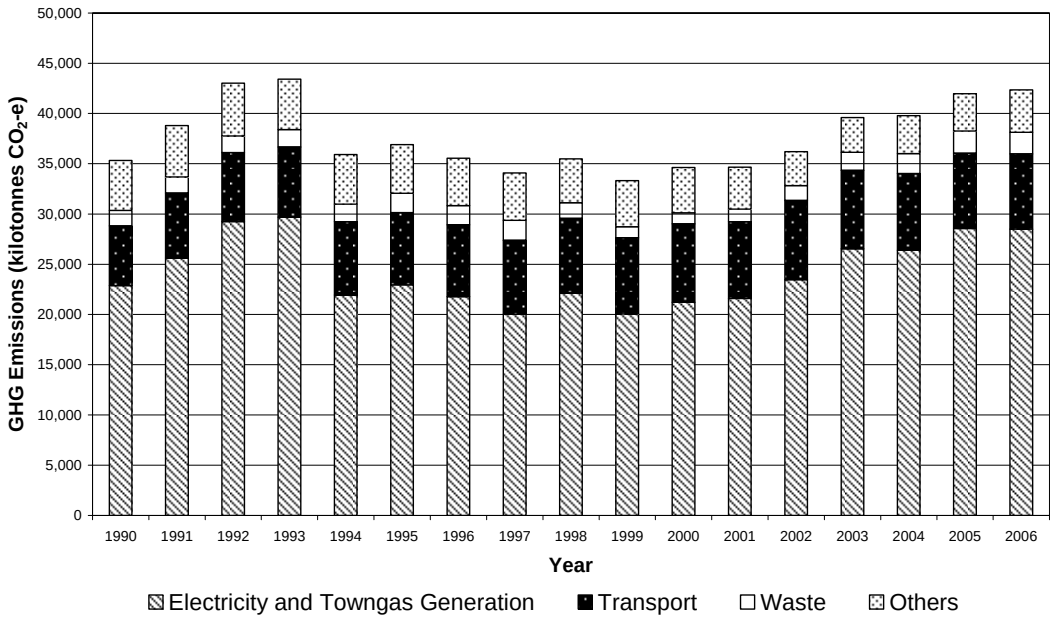
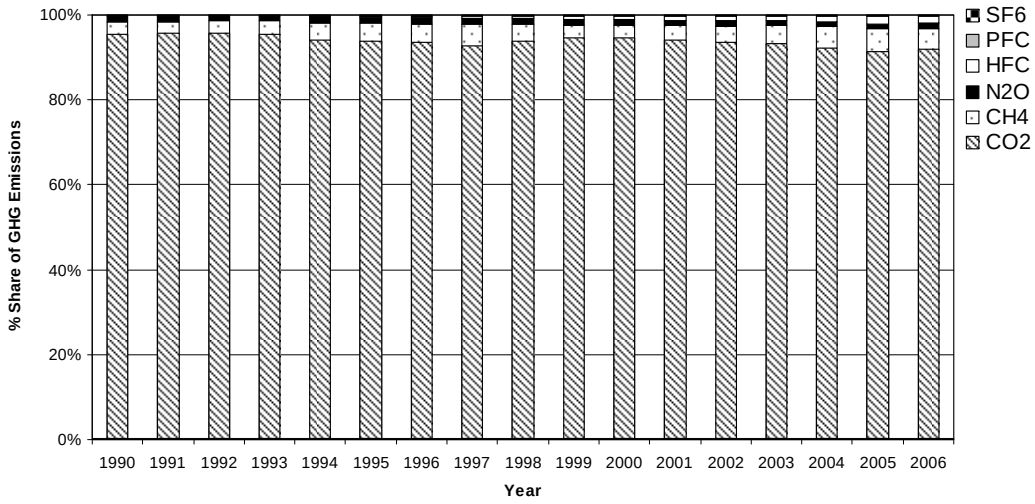


Figure 2.3 Total HK GHG Emissions from 1990 to 2006, by Gas Type



Prior to 1993, the total GHG emissions were gradually increasing but declined dramatically in the year 1994 largely due to the significant decrease in the emissions from the Energy sector as Hong Kong started to import nuclear power from mainland China.

It should be noted that all emissions from fuels for international aviation and marine travel and multilateral operations, in accordance with the Charter of the United Nations, are excluded from the total domestic inventory and reported separately as memo items. The inventory includes all domestic travel by air and sea, which is defined as all movements within the HKSAR.

2.3.2 *GHG Emissions by Gas and Sector*

Figure 2.3 shows the total emissions for each year, over the 17 year period, for each GHG. It can be seen that CO_2 is the dominant gas, accounting for at least 90% of total GHG emissions over the 17 years. CH_4 and N_2O contribute a maximum of approximately 5% and 2% of total, respectively, while the remaining gases have less than a 1% contribution each.

The emissions can be further disaggregated into the 2006 IPCC sectors - *Energy*, *Industrial Processes and Product Use (IPPU)*, *Agriculture Forestry and Land-Use Change (AFOLU)* and *Waste*. The GHG emissions by gas type for each sector are summarized in *Tables 2.3* and *2.4*.

Some of the principal observations on these data are summarised below.

- *Energy*: In the Energy sector, CO_2 is the most abundant GHG released into the atmosphere, followed by N_2O and CH_4. The GHG emissions released from the Energy sector increased consistently over the period studied, with the exception of a marked drop between 1993 and 1994, as noted previously.
- *IPPU*: GHG emitted from the IPPU sector are different in composition to the other sectors as they consist of CO_2, HFCs, PFCs, and SF_6 (all from product usage). Emissions of HFCs and PFCs were first documented in Hong Kong in 1995, whereas the CO_2 emissions were zero during the years 2002 to 2005 as a result of the temporary discontinuation of clinker production.
- *AFOLU*: A significant CO_2 removal is estimated from *Sector 3B – Land*. N_2O is the main GHG contributor and CO_2 is the smallest contribution in AFOLU without considering Sector 3B.
- *Waste*: There was a significant drop in GHG emissions from the Waste sector in 1999 and 2000 and then a gradual increase after 2000 for a number of reasons. Firstly the leachate treatment work (LTW) plants commenced operation in 1999 at the WENT landfill and the Tseung Kwan O (TKO) Stage I closed landfill. A large amount of LFG captured in the WENT landfill (at the rate of 4,400 m^3/hr) and the TKO Stage I closed landfill (at the rate of 1,300 m^3/hr) was utilized for the LTW operation as a source of energy. Secondly, LFG at the restored Shuen Wan landfill has been extracted and piped to Hong Kong and China Gas Company for utilization as a fuel since 1999, as a result, the net methane emissions in 1999 is significantly lower than the quantity emitted in the previous years. Finally, another LTW plant began to operate in 2000 at the NENT landfill and LFG was captured at a rate of 3,000 m^3/hr for utilisation in the LTW. As a result of the new LTWs starting operation, a significant drop of methane emissions from landfills is observed.

Table 2.3 GHG Emissions from Energy Sector, from 1990 to 2006

Year	HK GHG Emissions from Energy Sector ($GgCO_2$-e/year)			
	Domestic			
	CO_2	CH_4	N_2O	Total
1990	33,170	34	223	33,427
1991	36,190	37	218	36,445
1992	40,314	37	265	40,616
1993	40,547	39	273	40,860
1994	32,925	39	282	33,246
1995	33,621	41	288	33,950
1996	32,195	84	330	32,609
1997	30,484	109	366	30,959
1998	32,412	104	373	32,889
1999	30,610	112	373	31,095
2000	32,000	107	353	32,461
2001	31,981	111	357	32,450
2002	33,664	113	358	34,135
2003	36,764	93	314	37,172
2004	36,640	112	337	37,088
2005	38,378	114	322	38,814
2006	38,318	116	313	38,747

Table 2.4 *HK GHG Emissions from IPPU, AFOLU and Waste Sectors, from 1990 to 2006*

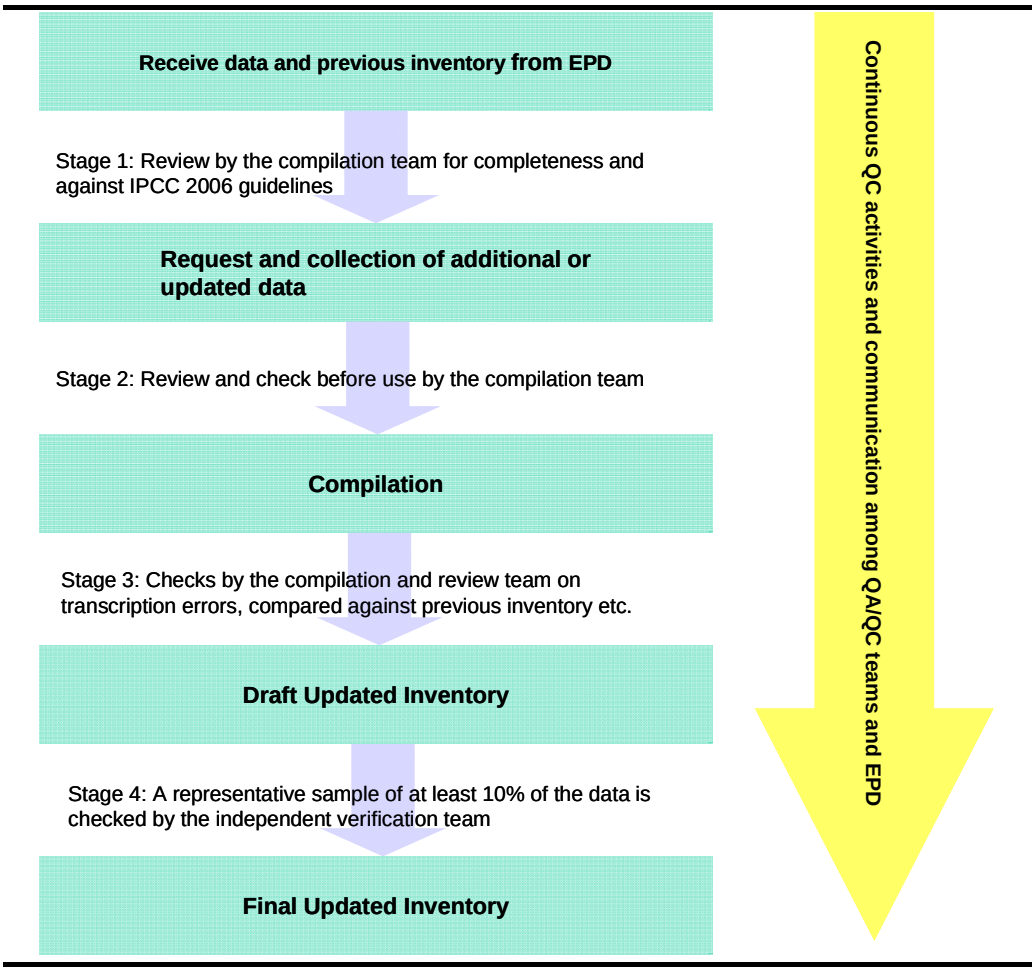
Year	HK GHG Emissions ($GgCO_2$-e/year)																
	IPPU					AFOLU								Waste			
						With Sector 3B				Without Sector 3B							
	CO_2	HFCs	PHCs	SF_6	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total
1990	113	0	0	102	215	-460	37	95	-328	9	37	95	141	338	1,058	152	1,548
1991	547	0	0	91	638	-459	29	84	-346	10	29	84	123	277	1,180	144	1,602
1992	544	0	0	108	651	-455	19	67	-368	14	19	67	100	228	1,284	144	1,656
1993	627	0	0	97	724	-461	18	62	-381	7	18	62	87	216	1,397	140	1,753
1994	703	0	0	127	830	-466	18	55	-392	3	18	55	77	127	1,502	141	1,769
1995	735	85	2	112	935	-455	19	52	-384	14	19	52	85	140	1,651	148	1,939
1996	724	113	2	112	952	-461	25	53	-383	8	25	53	86	137	1,614	150	1,902
1997	783	157	2	113	1,055	-467	26	48	-394	2	26	48	75	167	1,685	151	2,003
1998	689	191	3	95	977	-483	29	38	-416	3	29	38	70	32	1,389	127	1,548
1999	685	227	3	106	1,022	-408	34	40	-333	10	34	40	84	33	952	133	1,118
2000	599	283	4	91	977	-387	36	40	-311	2	36	40	78	34	955	125	1,114
2001	428	342	4	89	862	-368	38	44	-285	2	38	44	85	29	1,097	127	1,254
2002	0	390	2	112	503	-370	38	43	-289	1	38	43	82	29	1,328	131	1,488
2003	0	452	0	85	538	-383	31	41	-311	2	31	41	74	27	1,642	132	1,801
2004	0	541	2	93	636	-430	31	35	-364	2	31	35	67	26	1,836	133	1,995
2005	0	742	2	123	867	-412	31	42	-339	1	31	42	74	26	2,058	134	2,218
2006	535	739	0	108	1,383	-413	31	39	-344	5	31	39	74	21	1,989	133	2,142

2.3.3 *QA/QC and Uncertainty Analysis*

QA/QC

The emissions inventory was subjected to a series of checks to determine quality of the data, as illustrated in *Figure 2.4*. Further details of the process and the findings are presented in *Appendix A*.

Figure 2.4 Flowchart of the QA/QC Process



Uncertainty Analysis

A formal assessment of the uncertainty associated with the emissions estimates was undertaken in accordance with the recommendations of the *2006 IPCC Guidelines*. Details of the assessment methodology are presented in *Appendix A*.

The percentage uncertainty of the total inventory for 2005, excluding international transportation, is about 4.3% and the trend uncertainty is about 7.2%. When compared with the percentage uncertainty in the total inventory of other countries (eg New Zealand (20.7%) (1), Finland (15.9%) (2), US (-2 to

(1) Uncertainty calculation for the New Zealand Greenhouse Gas Inventory 1990-2005 excluding LULUCF removals (following IPCC Tier1), Table A7.2. http://www.mfe.govt.nz/publications/climate/nir-jul07/html/tablea7-2.pdf

(2) *2006 IPCC Guidelines* Volume 1 chapter 3 table 3.4

7%) [1], UK (14-15%) [2] and Japan (3%) [3]), the level of uncertainty in is considered comparable.

2.4 PROJECTED BASE CASE EMISSIONS, 2005 TO 2030

This section provides an overview of the emissions estimates for the period 2005 to 2030 under the Base Case, i.e. in the absence of any additional measures or policies to restrict or limit GHG emissions. The Base Case is then used as the benchmark against which emissions under alternative control scenarios are compared.

2.4.1 *Methodology for Base Case Development*

The Base Case was developed in the Hong Kong MARKAL-MACRO (HKMM) model which provides energy supply-demand projections in a detailed and disaggregated pattern. Although the Base Case projects a "business as usual" energy system path by incorporating existing and planned measures and development programs into the model, it should not be taken as the prevailing energy market for the future in the absence of additional mitigation policies and measures. Rather, it provides a reference basis to evaluate impacts of additional alternative scenarios, representing recommended policies and measures, to provide useful insights into the future and the impacts of these scenarios. The uncertainties inherent in any long-term scenario (eg GDP projection, population growth, future energy prices) suggest that, it is most useful to focus only on the differences in the results between the mitigation scenarios and the Base Case rather than on the absolute numerical results in a single scenario. It is the differences, not the absolute results that reflect the impact of the additional technologies, policies and measures.

The Reference Energy System (RES) underlying the MARKAL-MACRO modelling system requires input data (actual and projected) from primary energy supply (eg diesel fuel imports), intermediate conversion and process (eg electricity generation), to end-use technologies (eg air conditioners) that satisfy energy service demands (eg space conditioning). Each element in the RES is characterized by three groups of data: technical (eg efficiency), economic (eg capital cost), and environmental (eg carbon emission coefficient). *Table 2.5* shows the six main data input categories, including the four energy system building blocks depicted in *Figure 2.5*: resources/primary energy supply, conversion & process technologies, end-use technologies, and demand for energy services. The other two categories are economic parameters of energy carrier/technology and emission factors associated with elements within the four building blocks.

(1) U.S. Greenhouse Gas Inventory Reports 1990-2006, Annex 7 http://www.epa.gov/climatechange/emissions/downloads/08_Annex_7.pdf

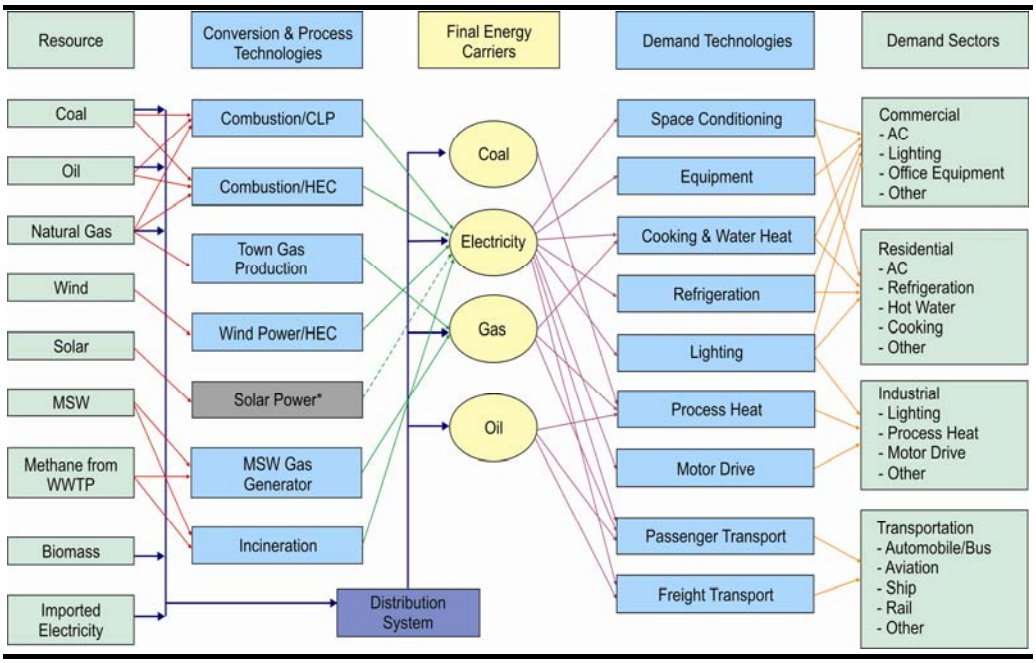
(2) UK NIR 2008 Annexes http://www.airquality.co.uk/archive/reports/cat07/0804161424_ukghgi-90-06_annexes_UNFCCCsubmission_150408.pdf

(3) National Greenhouse Gas Inventory Report of JAPAN (http://www-gio.nies.go.jp/aboutghg/nir/2008/NIR_JPN_2008_v4.0_E.pdf)

Table 2.5 Data Category

Data Category	Model Input
Demand for Energy Service; End-use Technologies	Demand Module
Conversion Technologies	Power Sector; Process
Primary Energy Supply	Resource
Price of energy carrier/technology	Price
Emission Factors	Emission Factors

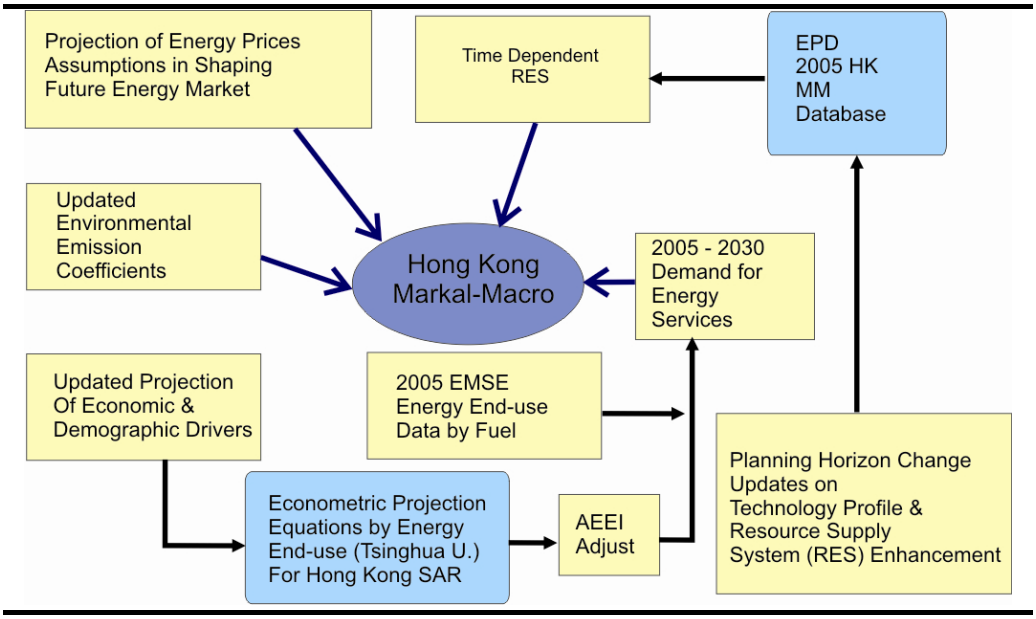
Figure 2.5 HK Simplified RES



Source: ERM and BNL.
Note: Technologies in gray boxes are those that can be developed in HK in the future.

Figure 2.6 depicts schematics of the interrelated tasks in the development of the Base Case. In general, Hong Kong specific historical energy demand-supply data were used to establish the base year (2005) RES in the Hong Kong MARKAL-MACRO model.

Figure 2.6 ***HKMM Baseline Dataflow***



Source: ERM and BNL.

2.4.2 *Base Case Results*

If there were no additional measures to control the emission of GHGs, emissions from Hong Kong are projected to increase, albeit in a non-linear manner, by 7% over the period 2005 to 2030. The major indicators for the Base Case derived from the HKMM model results are summarized in *Table 2.6*.

Table 2.6 ***Major Indicators: Base Case***

	2005	2020	2030	Total Growth 2005-2020 (%)	Total Growth 2005-2030 (%)	Annual Growth 2005-2030 (%)
Population (Thousand)	6,813	7,719	8,312	13	22	0.80
GDP (Billion 2005 HK$) (1)	1,383	2,258	2,905	63	110	3.01
Per Capita GDP (Thousand HK$)	203	293	349	44	72	2.20
Primary Energy (TJ) (2)	591,601	744,786	822,488	26	39	1.33
Final Energy (TJ) (3)	294,968	396,211	460,729	34	56	1.80
GHG Emissions (Million Tonnes $CO_{2\text{-}e}$)	42.0	46.1	44.8	10	7	0.26
Primary Energy Intensity (TJ/Billion HK$) (4)	428	330	283	-23	-34	-1.64
Final Energy Intensity (TJ/Billion HK$)	213	175	159	-18	-26	-1.18
Carbon Emissions per Capita (Tonnes $CO_{2\text{-}e}$) (5)	6.16	5.97	5.39	-3	-13	-0.53
Carbon Intensity (kg $CO_{2\text{-}e}$/ HK$)	0.0304	0.0204	0.0154	-33	-49	-2.68

	2005	2020	2030	Total Growth 2005-2020 (%)	Total Growth 2005-2030 (%)	Annual Growth 2005-2030 (%)

Notes:

(1) The GDP projections are based on the best available working assumptions for future economic growth. It is noted that the growth rate working assumptions from 2014 onwards are subject to a large degree of uncertainty.

(2) Primary energy is energy found in nature that has not been subjected to any conversion or transformation process. Examples of primary energy resources include coal, crude oil, sunlight, wind, running rivers, vegetation, and uranium.

(3) Final energy refers to the amount of energy consumed by final users for all energy purposes such as heating, cooking and driving machinery, but excludes non-energy usages such as using kerosene as solvent. It differs from primary energy in that the latter includes all energy used or lost in the energy transformation and the distribution process.

(4) Energy intensity is a measure of the energy efficiency of a nation's economy. It is calculated as units of energy per unit of GDP.

(5) Carbon intensity in this study is calculated as total GHG emissions per unit GDP.

The total primary energy consumption in the Base Case is projected to grow at an annual rate of 1.33% during the period 2005 to 2030, while the final energy demand is projected to grow at an annual rate of 1.80%. Compared to the projected 3.01% annual growth rate in GDP (1) over the same period, the decoupling trend between GDP and primary energy consumption implied in the annual growth rates is consistent with the historical data reported by the Census and Statistics Department (C&SD). The projected values in GDP, final energy demand and primary energy consumption imply that the final energy intensity will decrease from 213 TJ/Billion HK$ in 2005 to 159 TJ/Billion HK$ in 2030. The primary energy intensity, currently among one of the lowest in the world, will further decrease from 428 TJ/Billion HK$ to 283 TJ/Billion HK$ during the same period.

The annual growth rate of total carbon emissions (0.26% per year between 2005 and 2030) is projected to decouple from primary energy growth, which increases at an annual rate of 1.33% over the same period. In comparison, the total carbon emission grew at an annual rate of 1% during the period 1990 to 2006. The relatively low carbon emission growth rate projected is mainly due to the scheduled decommissioning of coal-fired power plant units in Hong Kong by 2030. The phase-out of existing coal-fired power plants and the assumption in the Base Case that they are replaced with high efficiency combined cycle gas turbines are the main factors that limit the carbon emission growth in Hong Kong. As a result, Hong Kong's carbon emission per GDP output, already one of the lowest in the world, is projected to continuously decrease from 0.0304 kg $CO_{2\text{-}e}$ per HK$ in 2005 to about 0.0154 kg $CO_{2\text{-}e}$ per HK$ in 2030. In terms of carbon emissions per capita, the model projects a very slight decrease (-0.53% per year for the period 2005 to 2030), based on the population growth rate provided by C&SD.

(1) The GDP projection and impact evaluated by the models is on the basis of real terms.

3 MITIGATION OF EMISSIONS

3.1 INTRODUCTION

The reduction of emissions of GHGs is widely acknowledged as being essential to averting the worst consequences of climate change. Contingent upon the prevailing local conditions and the sectors of concern, a wide range of measures is potentially available to reduce emissions. Emission reductions can be achieved by both reducing emissions from particular sources directly and through the widespread adoption of energy efficient technologies and practices.

The analysis of mitigation measures undertaken in the study utilises predominantly quantitative analyses of a set of scenarios to support the development of policy options. An integrated energy-economic-environmental modelling framework, the Hong Kong MARKAL-MACRO model, has been selected as the primary tool for this assessment. MARKAL represents the energy/environment system, captures the interactions between the various stages of the energy system and enables a wide range of energy resources and technologies to be analysed. MACRO is a macroeconomic model which is integrated with MARKAL to enable the aggregate economic consequences to be assessed. The solutions of the integrated model maximize social utility while assuring the least life-cycle costs in the energy system that meets the end-use service demands. More than 60 countries (including China) use country-specific MARKAL-MACRO models for GHG mitigation analysis. Further details of the model and its application are presented in *Appendix B*.

3.2 MITIGATION MEASURES

This study has approached the analysis of climate change mitigation measures on a sectoral basis. It focuses on four sectors that are main emission contributors in Hong Kong: electricity generation, buildings and appliances, transport and waste. *Table 2.2* and *Figure 2.2* demonstrate theses sectors' contribution to Hong Kong GHG emissions in 2005. As over 90% of Hong Kong's GHG emissions arise from the energy supply, use of energy in buildings and transport, and from landfills, the greatest potential for Hong Kong to further mitigate its GHG emissions lies within these sectors.

Key criteria for the selection of the policies and measures to be analysed were as follows:

- technical feasibility;
- no- or low-cost;
- maximising co-benefits;
- suitable for research, development and demonstration (RD&D).

Based on a local and international policy review, and with consideration of the key selection criteria, the study identified and shortlisted the following measures that were considered potentially suitable and feasible for implementation in the HKSAR before 2030 (1).

Building and Appliance Sector

- Expanding the scope and tightening the requirements of the Building Energy Codes (BEC) to achieve energy efficiency improvements of major installations (e.g lighting and lifts) in commercial buildings, expanding the use of district cooling systems (DCS)/water-cooled air conditioning systems (WACS) to reduce energy needs for cooling, and tightening the Overall Thermal Transfer Value (OTTV) (2) standards and promoting extensive use of green roofing, etc to reduce energy demands;

- Expanding the scope and tightening the requirements of the energy efficiency and performance standard of electrical appliances for domestic use;

- Improving the energy efficiency of commercial buildings through good housekeeping, information technology (IT) products or intelligent Building Environmental Management Systems (BEMS).

Transport Sector

- Widening the use of motor vehicles running on alternative fuel, including hybrid and electric vehicles (EVs);

- Introducing ethanol into the motor fuel mixture - petrol to be blended with a certain percentage of ethanol;

- Introducing biodiesel into the motor fuel mixture – diesel to be blended with a certain percentage of biodiesel;

- Implementation of a Hong Kong "Importers' Average Fleet Efficiency" standard (3).

Waste Sector

- Development of the Integrated Waste Management Facilities (IWMFs) and Organic Waste Treatment Facilities (OWTF) to recover renewable energy from municipal solid waste (MSW);

- Full utilization of the recovered landfill gas to produce energy;

- Full utilization of gas captured from wastewater treatment;

(1) Only quantifiable mitigation measures are listed.

(2) An OTTV is a measure of the energy consumption of a building envelop.

(3) The standard will set energy efficiency requirements for all new vehicles imported in Hong Kong.

- Full utilization of sludge treatment with energy recovery.

Electricity Generation

- Using more natural gas to generate electricity locally;
- Increasing the share of renewable energy (RE) in the overall fuel mix;
- Increasing the import of nuclear generated electricity from Mainland China.

3.2.1 Buildings and Appliances

End-use efficiency improvement to reduce the electricity generation output, which is applied on the demand-side, is among the most cost-effective of GHG emission control measures. The proportional contribution of various sources of GHG emissions in Hong Kong shows the potential significance of end use efficiency, particularly in electrical end uses.

Efficiency improvements in the end-uses have the potential to reduce peak loads, thereby reducing generation plant capacity requirements. This would bring economic benefits in addition to those associated with electrical energy and fuel savings, further off-setting the cost of investment in the more efficient equipment and thereby reducing the GHG emission reduction cost.

Many current technologies allow building energy consumption to be reduced through better thermal envelopes, improved design methods and building operations, more efficient equipment, and reductions in demand for energy services. Emerging areas for energy savings in commercial buildings include the application of controls and information technology to continuously monitor, diagnose and communicate faults in commercial buildings ("intelligent control"), and systems approaches to reduce the need for ventilation, cooling and dehumidification. Advanced windows, passive solar design, techniques for eliminating leaks in buildings, energy efficient appliances, and controlling standby and idle power consumption as well as solid-state lighting are also important in both residential and commercial sectors. Occupant behavior, including avoiding unnecessary operation of equipment and adaptive rather than invariant temperature standards for cooling, is also a significant factor in limiting building energy use (1).

Air conditioning and lighting are the most significant end-uses in Hong Kong. There are a range of technical options available for reducing the energy required to provide air conditioning services. These include using more efficient components (such as chillers) in central systems, more efficient packaged and room units, expanding the use of district cooling/water-cooled air conditioning system (WACS), and reducing the heat load on air conditioning plant by, for example, reducing the internal and external heat loads in buildings.

(1) IPCC, Climate Change 2007 Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

In order to promote the use of more energy efficient air-conditioning systems in Hong Kong, a pilot scheme for the use of fresh water for non-domestic air-conditioning in selected areas commenced in June 2000. In view of the support from the property owners and the environmental benefits, the Government decided to keep promoting the scheme in 2008 (1).

Lighting is a major end use. A survey of 80 studies show that efficient lighting technologies are among the most promising GHG-abatement measures in buildings in almost all countries, in terms of both cost-effectiveness and potential savings. There are many well known options to improve lighting efficiency available in the market, ranging from simple substitution of luminaries to the re-design of lighting systems. Lighting design, particularly commercial lighting design, is a complex and specialised field in its own right. Capturing efficiencies (and often simultaneous cost and employee productivity benefits) through better design is very building-specific.

Energy standards specifically aimed at appliances and equipment are widespread. Canada, Korea, Japan, the EU, the US and Singapore have all promoted such policies. Hong Kong's Voluntary Energy Efficiency Labelling Scheme (EELS), introduced in 1995, has been amended several times (most recently on 17 April 2008) and now covers 18 types of household and office appliances, including 10 types of electrical appliances (refrigerators, washing machines, compact fluorescent lamps, dehumidifiers, electric clothes dryers, room coolers, electric storage water heaters, television sets, electric rice-cookers and electronic ballasts, hot / cold bottled water dispensers), 7 types of office equipment (photocopiers, fax machines, multifunction devices, laser printers, LCD monitors, computers), domestic gas instantaneous water heaters. The *Energy Efficiency (Labelling of Products) Ordinance* of 9 May 2008 provides for a Mandatory Energy Efficiency Labelling Scheme (EELS) which currently covers room air conditioners, refrigerating appliances, and Compact Fluorescent Lamps (CFL).

Multiple obstacles exist and make it difficult to adopt more efficient technologies and realize the energy efficiency improvement potential in Hong Kong as rapidly as desired. These barriers include:

- availability of technology;
- higher costs of getting reliable information on energy efficient technology;
- limitations inherent in building designs;
- mixture of building ownership;
- allocation of costs and benefits associated with capital expenditure, i.e., the owners bear the cost while the tenants get the benefit;

(1) http://www.devb.gov.hk/en/publications_and_press_releases/publications/environmental_report/2008_environmental _report/2008_er_full_er/index.html

- cash flow constraints of some Small and Medium-sized Enterprises (SMEs) in relation to the initial investment cost; and

- lack of an appropriate portfolio of policies and programs.

The following measures may be considered by the Government to overcome these constraints:

- implement a mandatory scheme that sets energy efficiency targets for different types of buildings under the Building Energy Codes;

- use guidelines, training workshops and public campaigns to enhance the understanding of the stakeholders on the importance of building energy efficiency improvement and the mandatory scheme;

- financial support in the form of an environment fund, tax incentives and a loan funding scheme from power companies which could be used to encourage the enhancement of energy efficiency in buildings;

- implement the mandatory scheme in phases, with the priority focused on new buildings and the common areas of the buildings where the building owners/property managers have control and then extend the coverage to the tenant area in the long run;

- expand the scope and tighten the energy efficiency standards over time.

Consumer behaviour, including avoiding unnecessary operation of equipment and adaptive rather than invariant temperature standards for cooling, is also a significant factor in limiting building energy use. Information and education are important to promote climate-friendly consumer behaviour and thus help reduce energy demand.

3.2.2 Road Transportation

Transport is distinguished from other energy-using sectors by its predominant reliance on a single fossil resource and by the infeasibility of capturing carbon emissions from transport vehicles. It is also important to view GHG-emission reduction in conjunction with local air pollution, traffic management and energy security. Solutions therefore have to take into consideration of transportation problems as a whole, not just GHG emissions.

Mitigation measures includes vehicle efficiency improvement, alternate vehicle and fuel types (hybrid petrol-electric vehicles and petrol to bio-fuel blended petrol), as well as other policy options.

Vehicle Efficiency Improvement

Improved vehicle efficiency measures, leading to fuel savings, in many cases have net benefits, but the market potential is much lower than the economic potential due to the influence of other consumer considerations, such as performance. A major risk to the potential for future reductions in CO_2

emissions from the use of fuel economy technologies is that they can be used to increase vehicle power and size rather than to improve the overall fuel economy and cut carbon emissions. The preference of consumers for power and size has consumed much of the potential for GHG mitigation reduction achieved over the past two decades (1).

Alternative Vehicle and Fuel Types

Various forms of vehicle fuel switching measures are potentially feasible in Hong Kong, and include the following.

- *Diesel to LPG:* The Hong Kong SAR Government has already committed to changing taxis from diesel to LPG, principally as a measure to improve urban air quality. That measure and its associated policy instrument are included here to show the effect of the measure on GHG emissions. LPG could also be used for other small- to medium-sized diesel vehicles.

- *Bio-Fuel Mixtures*: The introduction of bio-fuels by mixing with traditional petro-fuels is a way of reducing net GHG emissions. Bio-fuels are considered GHG emission neutral, since the emission of CO_2 from the consumption of the fuels has already been off-set by the absorption of atmospheric CO_2 during the growth of the source crops. The GHG emission reduction possible is therefore a direct function of the proportion of fuel that can be substituted with bio-fuel. It is possible to mix a small proportion of bio-fuel such as methanol or ethanol with existing petrol, or biodiesel with diesel, without any change to existing engines (2). The introduction of biofuel such as adding ethanol to petrol could be more readily effected. No additional infrastructure or change to vehicle engines is required if, for example, all petrol is required to include a 10% bio-ethanol. Hence, it is assumed that biofuel can be introduced but some form of government support or regulation would be needed to encourage or require its use. Specifically, biodiesel produced from waste cooking oil should be considered.

- *Electric Vehicles:* Electricity produced from any primary energy source, with the exception of coal, is likely to offer significant CO_2 savings compared with petrol and diesel. Electric-powered cars could become increasingly prevalent in the future – for example, plug-in hybrids, running partly on electricity, could be commercial in a few years' time.

- *Hydrogen Vehicles:* Hydrogen produced from low-carbon sources can offer large carbon savings compared with petrol and diesel. In the short term, the scope to reduce the carbon intensity of the fuel mix through hydrogen is limited by the lack of availability and high cost of low-carbon hydrogen (except in special cases such as from intermittent electricity generation at

(1) IPCC, Climate Change 2007 Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007

(2) Julia King, The King's Review of low carbon cars, 2007, http://www.hm-treasury.gov.uk/king (accessed Sep 3 2009)

times of day when there is no other use for that power) along with the lack of available vehicles and supply infrastructure.

- There may also be scope for future innovative *future fuel developments* to contribute to CO_2 reductions from fuels.

Policy Instruments

A range of transport-focused policy instruments with potential for controlling GHG emissions were considered and include the following:

- *Road Pricing*: a road pricing scheme is usually used to overcome local traffic congestion problems. It may be expected to have some impact on GHG emissions, but the relationships are not straight-forward and are specific to particular schemes, geographical locations, local economic and transport sector conditions. Feasibility studies conducted previously conclude that the case for introducing road pricing in Hong Kong is considered weak (1) . From overseas experience, a road pricing scheme that aims to relieve traffic congestion can only be implemented equitably and effectively in the presence of alternative routes with adequate capacity for motorists to by-pass the charging zone. In the case of Hong Kong, such an alternative route is the Central-Wanchai Bypass (CWB) which will not be in place before 2017. While the case for road pricing implementation in Hong Kong as a measure to combat GHG emissions has yet to be established, there is a possibility that the measure could remain under consideration in the long term.

- *Replacement of Goods Vehicles*: the main target vehicle groups for replacement are old, inefficient vehicles and heavy goods vehicles. It is a practice which has been implemented in Hong Kong as well as in many other jurisdictions. The HKSAR Government from 1 April 2007 to 31 March 2010 offered a time-limited one-off grant to vehicle owners to replace their pre-Euro and Euro I diesel commercial vehicles with Euro IV compliant vehicles (2). Internationally, the State of California has several programs intended to phase out polluting or inefficient vehicles such as incentives for voluntary retirement of high emitting passenger cars and light- and medium-duty trucks as well as incentives to retrofit old polluting school buses (3). While Canada has committed CA$92 million over four years beginning in 2009 to create incentives for Canadians to trade in vehicles made in 1995 or earlier which do not meet today's emission standards for newer, more efficient vehicles (4).

- Emission reduction from *off-road vehicles and equipment:* electrification of vehicles and equipment operated at the airport and the ports has the

(1) According to the Transport and Housing Bureau (THB) of Hong Kong Government.

(2) http://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/old_diesel_com_veh_replace_prog.html#special_arrangement

(3) http://www.arb.ca.gov/ba/fininfo.htm

(4) http://www.ec.gc.ca/cleanair-airpur/Sustainable_Transportation/Vehicle_Scrappage_Program-WSF8711200-1_En.htm

potential to reduce GHG emissions from these sources. The electrification of port yard equipment is currently being considered by other jurisdictions and could be feasible for consideration in Hong Kong. The California Air Resources Board, California Climate Action Registry, and South Coast Air Quality Management District are considering the development of a protocol for the electrification of truck stops which would establish a standard methodology in determining greenhouse gas emission reduction from the use of electric power as opposed to a diesel-powered engine on a truck for idling purposes (1). As a port initiative, the Port of Long Beach is considering "Green-Container" Transport Systems which will involve broadening the use of electrification (from "green energy" sources) in port-related sources (2).

- Implementation of the Hong Kong "*Importers' Average Fleet Efficiency*" *Standard.* This Study examined a standard whereby the average imported vehicle efficiency should be 20% higher than the 2005 market average efficiency by 2015. This is an alternative to introducing an environmental tax on high emitting vehicles and its implementation cost would be relatively low.

- Given the positive effects of higher population densities on *public transport use, walking, cycling* and CO_2 emissions, further improved integrated spatial planning is an important policy element in the transportation sector.

- *Vehicle Information and Driver Education Programmes*: driving style affects fuel consumption and emissions. Information about opportunities to reduce vehicle fuel consumption could cover the vehicles themselves and driving style and habits. Vehicle energy labelling and driver education programmes should be considered.

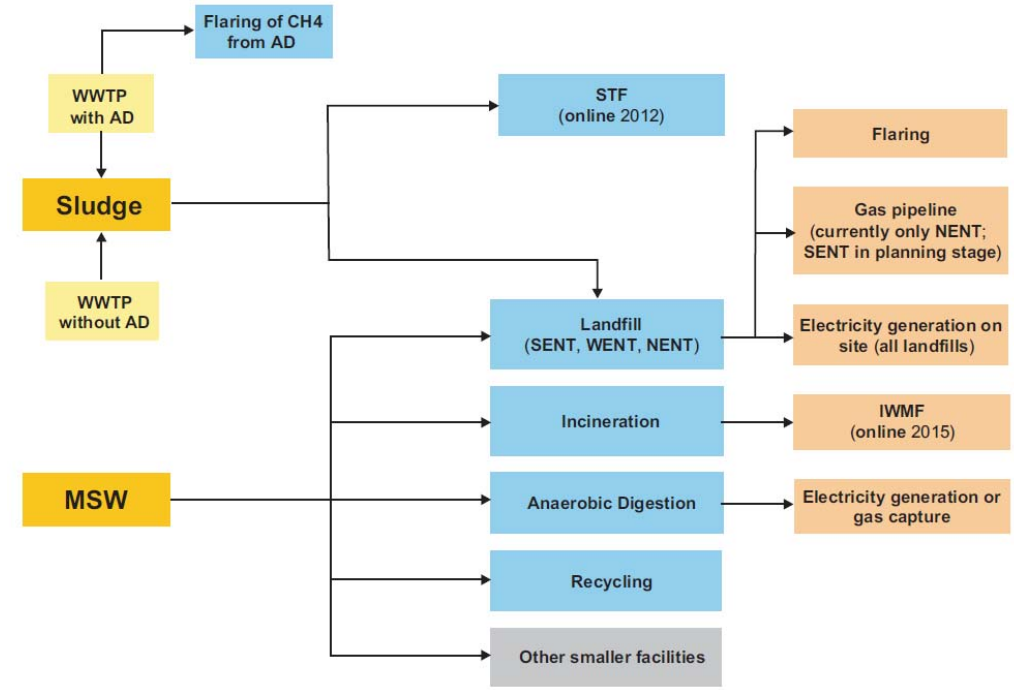
3.2.3 Waste

Figure 3.1 summarises the waste and wastewater management strategy in Hong Kong. Waste management is relevant from a climate change mitigation perspective as the anaerobic decomposition of organic material at landfill sites leads to the emission of methane (CH_4). A reduction in the amount of waste landfilled will reduce emissions.

(1) http://www.polb.com/civica/filebank/blobdload.asp?BlobID=6344

(2) http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3468

Figure 3.1 Waste and Wastewater Management in Hong Kong



The most relevant climate change mitigation measure in the waste sector in Hong Kong is the recovery and utilisation of landfill gas in operating and closed/restored landfills. The recovered landfill gas, which essentially consists of CO_2 and CH_4, can then either be utilised as an alternative energy source on-site or off-site, or flared as an alternative way of reducing emissions. At present, all three strategic landfills have been utilising landfill gas for energy production and/or for Towngas production (1). It is proposed that the landfill gas recovery rate would become higher, and there will be full utilisation of the landfill gas in the alternative mitigation scenarios.

With landfills expected to be exhausted earlier than first envisaged, the Government promulgated a policy framework in late 2005 with a view to manage Hong Kong's municipal solid waste in a sustainable manner. One element of the framework is the development of Integrated Waste Management Facilities (IWMF) that would adopt advanced incineration as the core waste treatment technology. The advanced technology, which is much cleaner than that of the incinerators previously operated in Hong Kong, involves high temperature combustion and allows for considerable power generation while reducing pressure on landfill sites substantially. The first phase of the IWMF would have a capacity of 3,000 metric tons per day and is planned to be commissioned by 2015 (2).

At present, all dewatered sewage sludge generated by sewage treatment works is disposed of at landfills in Hong Kong. This practice is not considered sustainable from both environmental and technical perspectives.

(1) All three strategic landfills have been partially utilising landfill gas for energy production and NENT has also been using landfill gas for Towngas production.

(2) http://www.epd.gov.hk/epd/english/environmentinhk/waste/prob_solutions/WFdev_IWMF.html

In 2009, the Director of Environmental Protection (DEP), with the support of the Secretary for the Environment, proposed to design and construct the Sludge Treatment Facilities (STF). The capacity of the currently planned STF is 2,000 tonnes per day. Depending on the actual sewage sludge arisings in future, future upgrading of the STF capacity or even a new STF may be required (1) .

EPD is also planning to develop large scale Organic Waste Treatment Facilities (OWTF) to recycle organic waste from institutions, commercial and industrial establishments. Operation of the OWTF would reduce disposal of organic waste to landfills and produce useful products including compost and renewable energy. The first phase of OWTF would have a 200 metric tonnes per day capacity and is planned to be commissioned by the mid 2010's. The second phase is of a similar capacity and its commissioning is anticipated in late 2010's.

In addition to GHG mitigation, improved sanitation and waste management provide a wide range of public health and environmental co-benefits.

3.2.4 Energy Supply

Hong Kong has a diverse energy supply resource mix. Electricity is generated locally from coal and natural gas and a substantial quantity of nuclear electricity is imported from Guangdong. Reticulated consumer gas supplies are in the form of town gas manufactured from naphtha and natural gas.

Increasing the import of nuclear generated electricity from Mainland China, using more natural gas to generate electricity locally, and increasing the share of renewable energy would help Hong Kong to reduce carbon emissions. The potential for adverse effects in the long term, such as reduction in the overall energy supply security and reliability in Hong Kong, would need to be carefully considered before abandoning coal-fired electricity generation and converting the reticulated supply network to natural gas.

- Natural Gas

In August 2008, a Memorandum of Understanding (MOU) was signed between the HKSAR Government and the Central Government for the supply of nuclear electricity and natural gas to Hong Kong for the coming two decades. The MOU provides an opportunity to draw natural gas from three sources: first, from new gas fields planned to be developed in the South China Sea; second, from the second east-west gas pipeline bringing gas from Turkmenistan; and third, from a Liquefied Natural Gas (LNG) terminal to be located in the Mainland.

(1) http://www.legco.gov.hk/yr08-09/english/fc/pwsc/papers/p09-16e.pdf

- Nuclear

If Hong Kong is to expand its electricity import capacity from the Mainland and within the SAR itself, it needs not only to enhance the existing Nuclear Transmission Network (NTS), but also to build new transmission infrastructure between Hong Kong and the Mainland. Actual project costs are uncertain and will be subject to final network design and construction methods. The project lead time after a decision to proceed with such a project would be more than 8 years to allow for planning, design, permitting, construction and commissioning.

- Renewable Energy

New energy infrastructure investments, upgrades of energy infrastructure, and policies that promote energy security, can, in many cases, create opportunities to achieve GHG emission reductions (1). Renewable energy, such as large scale wind and solar, requires significant initial investment and operational costs.

In 2005 the First Sustainable Development Strategy the Government set a target of 1 to 2% renewable energy in electricity use by 2012. In addition to the IWMF being planned, both CLP and HEC are currently planning to develop off-shore wind farms.

- Overall Considerations

Hong Kong may import more nuclear electricity from Mainland China and more natural gas to generate electricity locally. The marginal electricity prices of both natural gas and nuclear electricity are higher than that of coal, and the natural gas price is expected to increase rapidly in this region (2) . Although the impact from fuel price changes on Hong Kong's aggregate GDP growth is small, the change of fuel mix will influence the future electricity tariff.

Further challenges are likely to be presented by both the increased import of natural gas and nuclear power. Generation and network infrastructure takes a long time to implement, requiring the resolution of a range of engineering issues, permitting processes and liaison with stakeholders. Continued engagement between industry and different stakeholder groups is needed to enable the development of feasible engineering options that meet the required programme.

Climate change policy objectives and other policies such as improving air quality should be well integrated to avoid wasteful investments and adverse effects on electricity supply reliability. Utilities need to plan effectively on the basis of asset lives which span more than two decades. Clear emission

(1) IPCC, Climate Change 2007 Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

(2) "Natural Gas in China Market Evolution and Strategy", IEA, June 2009.

reduction targets at least for 2020 and 2030 are necessary for practical planning and sustainability assessment.

3.3 ALTERNATIVE SCENARIOS

Following a review of local and international practices and policies that can contribute to the reduction of GHG emissions, three alternate Scenarios were developed. Each Scenario represents a set of measures which, working together, deliver varying degrees of emissions reduction over differing timescales. *Table 3.1* summarises some of the key measures included within each Scenario and their possible progress. It should be noted that the Scenarios were developed for the purpose of analyzing the effectiveness of alternate packages of practices and policies and hence to inform a decision on the likely ranges of emissions reduction that may be viable in Hong Kong. There remains a degree of uncertainty both as to the practices and policies that will ultimately be adopted and the degree to which they are effective. The degree of uncertainty is greater in the 2020 to 2030 time period than in the period up to 2020 and hence the policies and measures assumed for the purposes of this analysis may well be subject to change.

Table 3.1 Key Scenario Assumptions

Measures	Scenario 1 (2005-2030)	Scenario 2 (2005-2030)	Scenario 3 (2005-2030)
Buildings and Appliances [1]			
Expanding the scope and tighten the requirements of the Building Energy Codes	0.6% energy saving of total energy consumption by 2015	Up to 50% energy saving of major installations in all new commercial buildings by 2020	Up to 50% energy saving of major installations in all new commercial buildings by 2020
Expanding the use of district cooling system (DCS)/water-cooled air conditioning system (WACS)	0.5% saving in total energy consumption by 2020	Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; All commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2030	Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; All commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2030
Reducing energy demand in new buildings through e.g. tightening the overall thermal transfer value (OTTV) standards and promoting wider adoption of green roofing	N/A	Up to 50% cooling demand reduction in all new commercial buildings by 2020	Up to 50% cooling demand reduction in all new commercial buildings by 2020
Expanding the scope and tightening the energy efficient electrical appliance standards for domestic use	0.3% energy saving of total energy consumption by 2015	Appliances sold in the market in 2020 will be up to 25% more energy efficient, compared with 2005 level; Appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level	Appliances sold in the market in 2020 will be up to 25% more energy efficient, compared with 2005 level; Appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level
Improving energy efficiency from Building Environmental Management System	N/A	Up to 15% energy efficiency improvement in up to 25% of existing commercial buildings by 2020; Up to 15% energy efficiency improvement in all existing commercial buildings by 2030	Up to 15% energy efficiency improvement in up to 25% of existing commercial buildings by 2020; Up to 15% energy efficiency improvement in all existing commercial buildings by 2030
Transport			
Wider use of motor vehicles running on alternative fuel	2020: Hybrid/EV or other vehicles with similar performance: 30% private cars, 15% buses, 15% HGV and LGV 2030: Hybrid/EV or other vehicles with similar performance: 50% private cars, 50% buses, 50% HGV and LGV	2020: Hybrid/EV or other vehicles with similar performance: 30% private cars, 15% buses, 15% HGV and LGV 2030: Hybrid/EV or other vehicles with similar performance: 50% private cars, 50% buses, 50% HGV and LGV	2020: Hybrid/EV or other vehicles with similar performance: 30% private cars, 15% buses, 15% HGV and LGV 2030: Hybrid/EV or other vehicles with similar performance: 50% private cars, 50% buses, 50% HGV and LGV
Petrol blended with 10% Ethanol (E10)	N/A	All petrol to be blended with 10% of ethanol by 2020	All petrol to be blended with 10% of ethanol by 2020
Diesel blended with 10% Biodiesel (B10)	N/A	All diesel to be blended with 10% of biodiesel by 2020	All diesel to be blended with 10% of biodiesel by 2020
Implementation of "Importers' Average Fleet Efficiency" standard	N/A	New vehicles will be 20% more energy efficient than the 2005 market average by 2020	New vehicles will be 20% more energy efficient than the 2005 market average by 2020
Waste			
Construction and operation of waste-to-energy facilities	N/A	One IWTF with a treatment capacity of 3,000tonnes/day by 2020; Sufficient IWMFs to treat all MSW in HK by 2030. Two OWTFs operating at a total capacity of 400 tonnes per day by 2020.	One IWTF with a treatment capacity of 3,000tonnes/day by 2020; Sufficient IWMFs to treat all MSW in HK by 2030. Two OWTFs operating at a total capacity of 400 tonnes per day by 2020.
Utilization of landfill gas as energy source	N/A	Full utilization of recovered landfill gas	Full utilization of recovered landfill gas
Utilization of gas generated from wastewater treatment	N/A	Full utilization	Full utilization

Measures	Scenario 1 (2005-2030)	Scenario 2 (2005-2030)	Scenario 3 (2005-2030)
Utilization of sludge treatment with energy recovery	N/A	One sludge treatment facility operating at full capacity	One sludge treatment facility operating at full capacity
Energy Supply			
Use of coal in electricity generation	All power plants retire according to their expected life	All power plants retire according to their expected life	Accounting for less than 10% of fuel mix in 2020; zero in 2030
Use of natural gas in electricity generation	Natural gas makes up the balance of the share of the overall fuel mix, after taking account of RE, nuclear import and remaining coal	Natural gas makes up the balance of the share of the overall fuel mix, after taking account of RE, nuclear import and remaining coal	Making full use of natural gas supply guaranteed by the Mainland under the relevant Memorandum of Understanding (MOU) on Energy Co-operation (2)
Import of nuclear generated electricity	Maintained at the same level as in 2005	Maintained at the same level as in 2005 until 2020; meeting 35% of the local demand for electricity 2030	Nuclear electricity imported from the Mainland to meet 50% of the local demand for electricity from 2020 (2)
Renewable energy (RE) (3)	Meeting 4% of the local demand for electricity by 2020; 6% by 2030	Meeting 4% of the local demand for electricity by 2020; 15% by 2030	Meeting 3-4% of the local demand for electricity by 2020; 4% in 2030

Notes

(1) The purpose of the Study is to assess the impacts of various mitigation measures and scenarios on GHG emission abatements. Measures and assumptions in mitigation scenarios are based on international technology and policy reviews. They are not implementation targets, but provide an envelope within which the impacts of alternative assumptions can be inferred. Detailed feasibility studies for individual measures are required at later stages, taking into account limitations, uncertainties and practicability of the measures within Hong Kong's local context.

(2) Assumptions provided by the Government.

(3) RE includes wind energy, and energy recovered from landfill gas (LFG), Integrated Waste Management Facilities (IWMF) and Organic Waste Treatment Facilities (OWTF). Scenarios 1 and 2 include RE imported from the Mainland, although the availability of this additional amount of RE sources in the neighbouring areas which may be able to supply electricity to Hong Kong in a technically feasible and cost-effective manner is subject to further studies.

3.3.1 Scenario 1

Scenario 1 (the 'AQO Scenario') includes relevant mitigation measures proposed in the AQO Study (1), including the increased use of natural gas and renewable energy sources for electricity generation, wider use of road vehicles using clean fuels, and enhanced energy efficiency in the building and appliance sector. It required some refinement of the AQO policy options for the following reasons.

- The AQO Study options were considered individually rather than in combination and thus not compatible with MARKAL-MACRO (MM), which is a dynamic macroeconomic model and considers measures in an integrated manner.

- For a number of options examined in the AQO Study, the required input parameters and assumptions for the HK MM model were not available. In these cases ERM and BNL have made assumptions based upon our understanding of the particular policy or measure (as implemented internationally) and/or the technology in question.

- Some measures proposed in the AQO Study were not assessed in the HKMM model either because they are not associated with GHG reduction or because they are not considered to be commercially viable within the necessary timeframe.

Specifically, Scenario 1 assumes the following.

Building and Appliance Sector (2)

- Annual 0.6% energy saving in total energy consumption in Hong Kong from energy efficiency improvement through mandatory implementation of Building Energy Code (BEC) by 2015.

- 0.011% energy saving in total energy consumption in Hong Kong from energy efficiency improvements in street lighting and traffic signals by 2020.

- 0.5% energy saving in total energy consumption in Hong Kong from district cooling system by 2020.

- 0.3% energy saving of total energy consumption in Hong Kong from energy efficiency improvements in electrical appliances for domestic use by 2015.

Transport Sector

- Wider use of hybrid, electric powered, and biodiesel vehicles:

(1) Review of Air Quality Objectives and Development of a Long Term Air Quality Strategy for Hong Kong, July 2009.

(2) All energy saving information is based on the AQO Study assumptions.

- Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2020: 30% private cars, 15% buses, 15% HGVs and LGVs

- Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2030: 50% private cars, 50% buses, 50% HGVs and LGVs

Electricity Generation

- All power plants will retire according to their expected life.

- RE is to meet 4% of the local demand for electricity by 2020 and 6% by 2030 (including RE generated locally or imported from the Mainland) (1).

- Import of nuclear power maintained at the same level as in 2005.

- Apart from electricity generated by RE, nuclear, and remaining coal, all other local electricity consumption is from natural gas by 2030.

3.3.2 Scenario 2

Scenario 2 (the 'Accelerated Scenario') builds upon Scenario 1 and includes additional efforts on measures to increase energy efficiency and reduce energy demand, particularly in the building and transport sectors. Local sources of renewable energy such as waste-to-energy facilities are utilised by 2020. This scenario also assumes a certain level of integration of the power system between Hong Kong and its neighbouring areas. Electricity imported from Mainland China in 2020 is the same as that in 2005. In 2030, the scenario assumes, as a stress test, the notion that 50% of the electricity demand could be met by sources from the Mainland with no associated carbon emissions (2). Specifically, Scenario 2 assumes the following.

Building and Appliance Sector

- Up to 50% energy saving of major installations in all new commercial buildings through measures such as expanding the scope, and tightening the requirements of the Building Energy Codes by 2020.

- 0.011% energy saving in total energy consumption in Hong Kong from energy efficiency improvements in street lighting and traffic signals by 2020.

- Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; up to 50% energy efficiency improvement in all commercial buildings through measures such as expanding the use of district cooling system (DCS) and water-cooled air conditioning system

(1) In 2005 the First Sustainable Development Strategy sets a target of 1~2% RE in electricity use by 2012.

(2) This excludes remaining coal power plant generation. Among the electricity with no associated carbon emissions, 70% is from import of nuclear generated electricity.

(WACS). Energy efficiency improvement is compared with that of the regular air conditioning system.

- Up to 50% cooling demand reduction by 2020 in all new commercial buildings from measures such as new overall thermal transfer value (OTTV) standards and extensive green roofing.

- Appliances sold in the market in 2020 will be up to 25% more energy efficient; appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level by expanding the scope and tightening energy efficient electrical appliance standards.

- Up to 15% Energy efficiency improvement in up to 25% of existing commercial buildings by 2020; up to 15% energy efficiency improvement in all existing commercial buildings from improving energy efficiency from Building Environmental Management System by 2030.

Transport Sector

- Wider use of hybrid and electric powered vehicles (EV):
  - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2020: 30% private cars, 15% buses, 15% HGVs and LGVs.
  - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2030: 50% private cars, 50% buses, 50% HGVs and LGVs.

- Petrol blended with 10% ethanol by 2020 (E10) (1).

- Diesel blended with 10% biodiesel by 2020 (B10) (2).

- Implementation of the Hong Kong "Importers' Average Fleet Efficiency" standard by 2020 - new vehicles will be 20% more energy efficient than the 2005 market average.

Waste Sector

- Waste-to-energy facility:
  - One IWMF with a treatment capacity of 3,000 tonnes/day by 2020.
  - Sufficient IWMFs to treat all MSW in HK by 2030.
  - Two OWTFs operating at full capacity of 400 tonnes per day by 2020.

(1) All petrol contains a mixture of 10% ethanol by volume. Blends of ethanol above 10% are assumed to need engine modification.

(2) B5 Biodiesel, is comprised of a "blend" of 10% Biodiesel and 90% petroleum diesel. Blends biodiesel above 10% might need engine modification.

(5) The current conclusion that GDP and its growth will not be materially affected in the alternative scenarios against the Base Case is made based on the currently available information. The economic modelling is at a macro scale, and the detailed economic impact of individual measure should be subject to further assessment at a later stage. In

- Full utilization of the recovered landfill gas.
- Full utilization of gas generated from waste water treatment.
- One sludge treatment facility operating at full capacity by 2020.

Electricity Generation

- All power plants retire according to their expected life.
- Import of nuclear power maintained at the same level until 2020; approximately 50% of local electricity consumption by 2030 is from sources in the Mainland with no associated carbon emissions.
- Apart from electricity generated by RE, nuclear, and remaining coal, all other local electricity consumption is from natural gas by 2030.

3.3.3 Scenario 3

Scenario 3 (the 'Aggressive Scenario') builds upon Scenario 2 and accelerates the integration of the power system in Hong Kong with its neighbouring areas. It assumes that Hong Kong would make full use of the natural gas supply guaranteed by the Mainland under the relevant Memorandum of Understanding (MOU) on Energy Co-operation for electricity generation. It also assumes that nuclear electricity imported from the Mainland would be able to meet 50% of the local demand for electricity from 2020. Specifically, Scenario 3 assumes the following.

Building and Appliance Sector

- Up to 50% energy saving of major installations in all new commercial buildings through measures such as expanding the scope, and tightening the requirements of the Building Energy Codes by 2020.
- 0.011% energy saving in total energy consumption in Hong Kong from energy efficiency improvements in street lighting and traffic signals by 2020.
- Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; up to 50% energy efficiency improvement in all commercial buildings through measures such as expanding the use of DCS and WACS. Energy efficiency improvement is compared with that of the regular air conditioning system.
- Up to 50% cooling demand reduction by 2020 in all new commercial buildings from measures such as new OTTV standards and extensive green roofing.

- Appliances sold in the market in 2020 will be up to 25% more energy efficient; appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level by expanding the scope and tightening energy efficient electrical appliance standards.

- Up to 15% Energy efficiency improvement in up to 25% of existing commercial buildings by 2020; up to 15% energy efficiency improvement in all existing commercial buildings from improving energy efficiency from Building Environmental Management System by 2030.

Transport Sector

- Wider use of hybrid and electric powered vehicles (EV):
    - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2020: 30% private cars, 15% buses, 15% HGVs and LGVs.
    - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2030: 50% private cars, 50% buses, 50% HGVs and LGVs.

- Petrol blended with 10% ethanol by 2020 (E10).

- Diesel blended with 10% Biodiesel by 2020 (B10).

- Implementation of the Hong Kong "Importers' Average Fleet Efficiency" standard by 2020 - new vehicles will be 20% more energy efficient than the 2005 market average.

Waste Sector

- Waste-to-energy facility:
    - One IWMF with a treatment capacity of 3,000 tonnes/day by 2020.
    - Sufficient IWMFs to treat all MSW in HK by 2030.
    - Two OWTFs operating at full capacity of 400 tonnes per day by 2020.

- Full utilization of the recovered landfill gas.

- Full utilization of gas generated from wastewater treatment.

- One sludge treatment facility operating at full capacity by 2020.

Electricity Generation

- 10% coal penetration in 2020, and zero in 2030.

- Making full use of natural gas supply guaranteed by the Mainland under the relevant Memorandum of Understanding (MOU) on Energy Co-operation for electricity generation.

- Nuclear electricity imported from the Mainland would be able to meet 50% of the local demand for electricity from 2020.

- Local RE sources are sufficient to meet 3-4% of local electricity consumption in 2020, and 4% in 2030.

- No primary energy source accounts for more than around 50% of Hong Kong's total electricity supply.

3.4 SCENARIO ANALYSIS

This section evaluates the impact and cost-effectiveness of the three alternative scenarios by comparing the key model outputs with the Base Case. The key criteria used for evaluating the policies and measures in subsequent sections by the HKMM model are categorized in the three basic types of costs and benefits:

- **Energy:** effects on energy flow and technological activities, such as oil and gas imports, electricity generation capacity mix, etc.

- **Environmental:** effects on GHG emissions and local air pollutants.

- **Economic:** effects on GDP and marginal abatement cost of carbon.

3.4.1 Carbon Emissions Abatement and GDP Impact

Table 3.2 shows that the total annual carbon emission in 2030 falls to 39.3 million tonnes $CO_{2\text{-}e}$ for Scenario 1, 29.8 million tonnes $CO_{2\text{-}e}$ for Scenario 2, and 26.8 million tonnes $CO_{2\text{-}e}$ for Scenario 3, down from 44.8 million tonnes $CO_{2\text{-}e}$ projected for the Base Case. The reduced emissions in 2030 are 6%, 29% and 36% below the 2005 carbon emission level for Scenarios 1, 2 and 3, respectively. In the Base Case emissions were predicted to be 7% above the 2005 level by 2030.

Table 3.2 GHG Emissions in Hong Kong by Scenario (Million Tonnes $CO_{2\text{-}e}$)

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	42.0	46.1	44.8	10%	7%
Scenario 1	42.0	43.0	39.3	2%	-6%
Scenario 2	42.0	41.9	29.8	0%	-29%
Scenario 3	42.0	29.5	26.8	-30%	-36%

Results of Scenario 1 show that although co-benefits from measures targeted at improving air quality are found to be large, and may help to offset mitigation costs, they alone are unlikely to provide sufficient incentives to achieve an aggressive GHG emission reduction target.

Scenarios 2 and 3 deliver substantive reductions in emissions over the planning period, with Scenario 3 achieving reductions most rapidly due to the earlier introduction of more imported electricity into Hong Kong.

As shown in *Table 3.3*, the GDP is projected to grow at an annual average growth rate of 3.01% in the Base Case from 2005 to 2030, and it is not predicted to be materially affected under the alternative scenarios. This is attributable to a variety of factors including energy efficiency measures, which will generate long-term savings in energy costs (5) .

Table 3.3 ***GDP in Hong Kong by Scenario (Billion 2005 HK $)***

	2005	2020	2030	2020 vs. 2005 Annual average growth rate	2030 vs. 2005 Annual average growth rate
Base Case	1,383	2,258	2,905	3.32%	3.01%
Scenario 1	1,383	2,263	2,916	3.34%	3.03%
Scenario 2	1,383	2,264	2,928	3.34%	3.05%
Scenario 3	1,383	2,270		3.36%	3.07%

3.4.2 Carbon Intensity

In 2005, the carbon intensities in Hong Kong, both in terms of GHG emissions per GDP value or on a per capita basis were among the lowest in the world's developed economies (1) . As shown in *Table 3.4* and *Figure 3.2*, the intensity against GDP in 2030 is projected to decrease to 0.0154, 0.0135, 0.0102, and 0.0091 kg $CO_{2\text{-}e}$ / HK$GDP by 2030 in the Base Case, Scenario1, Scenario 2, and Scenario 3, respectively, from the current level of over 0.0304 kg $CO_{2\text{-}e}$ / HK$GDP. It should be noted that Scenario 3 outperforms the Mainland target of reducing energy related carbon intensity of 40% to 45% by 2020 (2).

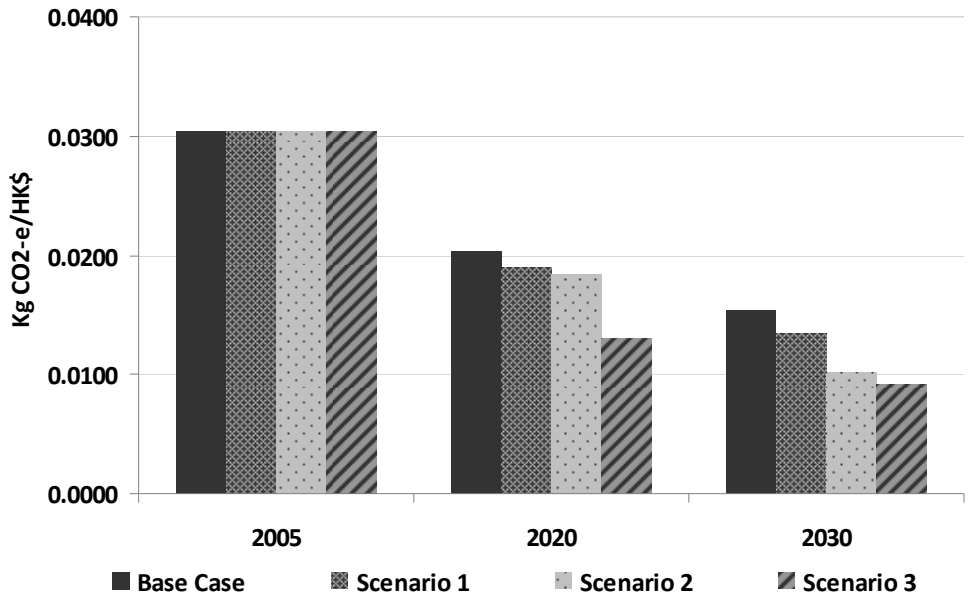
(1) http://www.iea.org/country/maps/world/co2_pop.htm; http://www.iea.org/country/maps/world/co2_gdp.htm (accessed on Oct 8 2009)

(2) The national carbon intensity target refers to the energy related CO2 per GDP value, while carbon intensity presented in this Study refers to total GHG emissions per GDP value. Hong Kong will control GHG emissions from all sources, including non-energy related carbon emissions such as methane from landfills, and thus the carbon intensity target includes all types of GHG emissions.

Table 3.4 ***Carbon Intensity (GHG Emissions per unit GDP in kg CO_2-e / HK$)***

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	0.0304	0.0204	0.0154	-33%	-49%
Scenario 1	0.0304	0.0189	0.0135	-37%	-56%
Scenario 2	0.0304	0.0185	0.0102	-39%	-66%
Scenario 3	0.0304	0.0130	0.0091	-57%	-70%

Figure 3.2 ***Carbon Intensity (GHG Emissions per unit GDP in kg CO_2-e / HK$)***

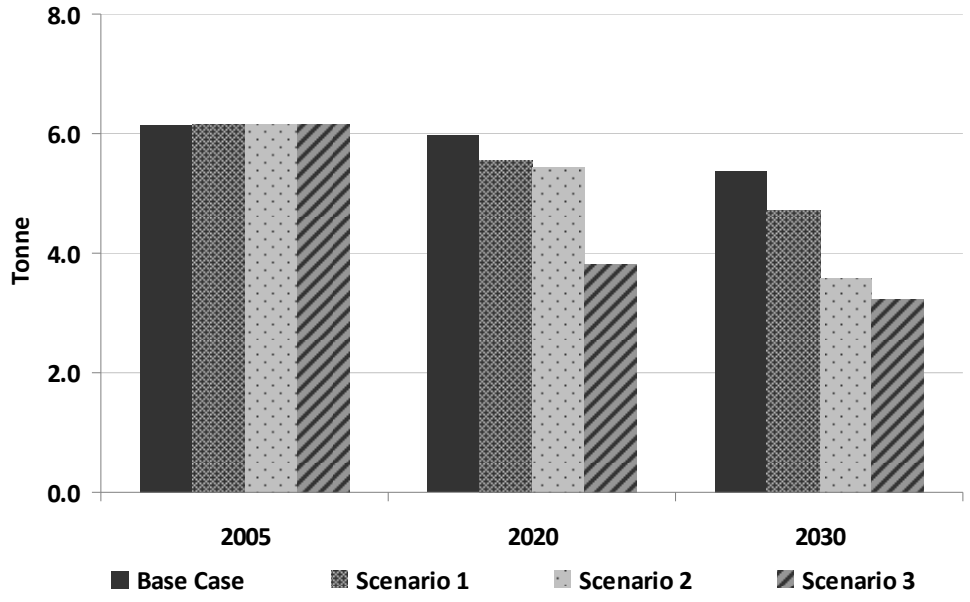


As shown in *Table 3.5* and *Figure 3.3*, carbon emissions per capita are predicted to fall from 6.2 tonnes to 5.6, 5.4, and 3.8 tonnes $CO_{2\text{-}e}$ for Scenarios 1, 2 and 3, respectively by 2020. The corresponding projected figures for 2030 are 4.7, 3.6, and 3.2 tonnes $CO_{2\text{-}e}$ per capita, respectively. Except for Scenario 3, both measures of carbon intensity are projected to drop at a faster rate between 2020 and 2025 in all cases because most of the existing coal-fired power plant units are scheduled to decommission during this period.

Table 3.5 ***Carbon Emissions per Capita (Tonne CO_2-e)***

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	6.16	5.97	5.39	-3%	-13%
Scenario 1	6.16	5.57	4.72	-10%	-23%
Scenario 2	6.16	5.43	3.58	-12%	-42%
Scenario 3	6.16	3.83	3.23	-38%	-48%

Figure 3.3 Carbon Emissions per Capita (Tonne CO_2-e)



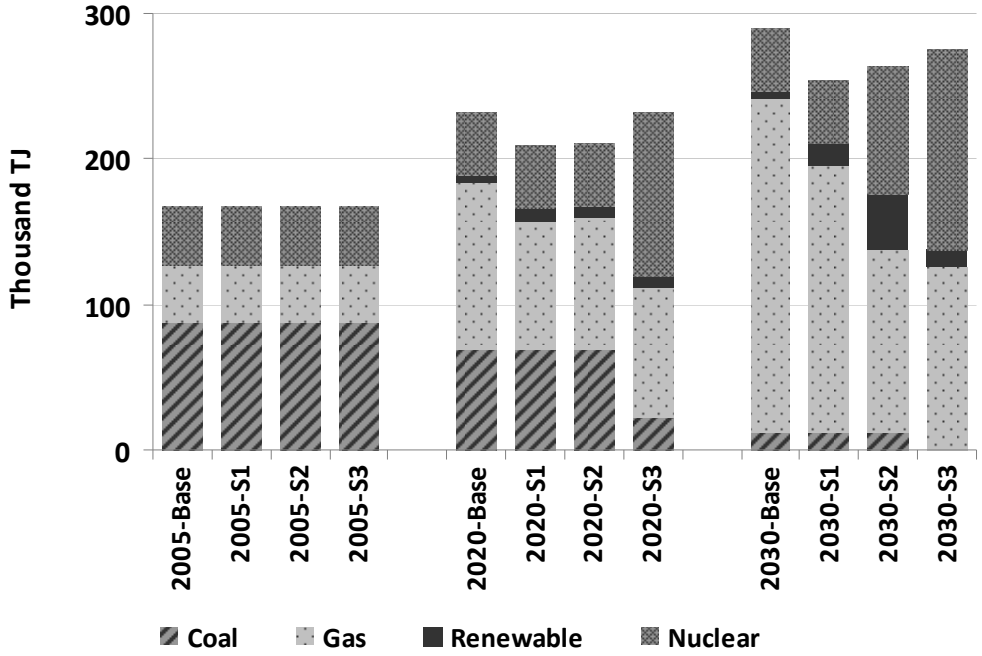
3.4.3 Electricity Output

In Hong Kong, electricity is the dominant energy carrier, accounting for more than 50% of the final energy use in 2005. This market share is projected to increase to over 60% in 2030 in the Base Case. The future may see two contradicting trends: on the one hand, more efficient end-use devices reduce electricity demand, whereas new electricity-using devices such as electric cars may be introduced to replace conventional gasoline vehicles, as assumed in the three mitigation Scenarios, thereby increasing the electricity use in the transportation sector.

Figure 3.4 presents the electricity output by source as well as the fuel mix in 2020 and 2030 for the different scenarios. In 2005, coal has the largest share and generates about 50% of electricity in Hong Kong. Under the Base Case, natural gas will progressively replace coal and generate approximately 80% of the electricity in 2030.

Under Scenario 3, no coal will be used for electricity generation in 2030. Natural gas used for electricity generation doubles in 2020, and almost triples in 2030, compared to the quantity used in 2005. Electricity from natural gas is projected to grow to 46% of the total. Electricity from renewable energy is expected to grow from less than 1% in 2005 to 4% of the total in 2030. Electricity from nuclear sources in the Mainland China in 2030 is expected to be more than three times the quantity used in 2005. It is projected to account for approximately half of the electricity usage beginning in 2020.

Figure 3.4 Electricity Output by Source (Thousand TJ)



The use of renewable resources, such as wind, reduces carbon emissions but is more costly than conventional electricity generation. The higher cost of electricity tends to lower those energy service demands requiring high electricity intensity devices to meet them. On the other hand, imports of natural gas in the future are projected to be more costly than at present, which may make electricity generated by gas-fired generation in Hong Kong more expensive than the nuclear electricity imports from Mainland China.

3.4.4 Reduction in Other Air Pollutants from Power Generation

There is a potentially large and diverse range of co-effects from climate change mitigation policies, which lower the net costs of emission reductions and thereby may strengthen the incentives to reduce emissions. Many recent studies have demonstrated significant benefits of carbon-mitigation strategies on human health, mainly because they also reduce other emissions, for example, SO_2, NO_x and particulate matter. This is projected to result in improvements to air quality and the prevention of some premature deaths due to air pollution. Quantification of mortality risks remains controversial, and hence a large range of benefits estimates can be found in the literature (1).

In the HKMM model, we have built in the emission coefficients for SO_2, NOx, and PM_{10} for power plants. Based on the projected fuel use by the sector to meet demand at market equilibrium, the model is able to account for the total emissions for these air pollutants, as shown in *Tables 3.6, 3.7* and *3.8*.

(1) IPCC, Climate Change 2007 Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

Table 3.6 Sulphur Dioxide from Electricity Generation (Thousand Tonnes)

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	61.5	11.1	4.3	-82%	-93%
Scenario 1	61.5	11.0	4.1	-82%	-93%
Scenario 2	61.5	11.0	3.8	-82%	-94%
Scenario 3	61.5	5.0	0.6	-92%	-99%

Table 3.7 Nitrogen Oxides from Electricity Generation (Thousand Tonnes)

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	42.2	34.6	24.3	-18%	-42%
Scenario 1	42.2	32.7	20.4	-23%	-52%
Scenario 2	42.2	34.4	15.5	-19%	-63%
Scenario 3	42.2	16.8	10.6	-60%	-75%

Table 3.8 Particulates (PM10) from Electricity Generation (Thousand Tonnes)

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	1.9	0.9	0.6	-52%	-70%
Scenario 1	1.9	0.9	0.5	-55%	-75%
Scenario 2	1.9	0.9	0.4	-55%	-80%
Scenario 3	1.9	0.4	0.2	-78%	-88%

Compared with the Base Case for the year 2005, the results show that in 2030:

- Sulphur dioxide emissions reduce by over 90% in all Scenarios by 2030;
- By 2030 nitrogen oxides emissions reduce by 52%, 63%, and 75% in Scenarios 1, 2, and 3, respectively;
- PM10 emissions reduce by 75%, 80%, and 88% in Scenarios 1, 2, and 3, respectively, by 2030 (1).

These estimates should be used for indicative purposes only and have the following limitations:

- The estimates are based on the average emission rates for the existing assets and are not responsive to the change due to future decommissioning of individual units.
- The exact operation and fuel use of each unit in the future cannot be reliably determined.

3.4.5 Scenario Analysis by Mitigation Sectors

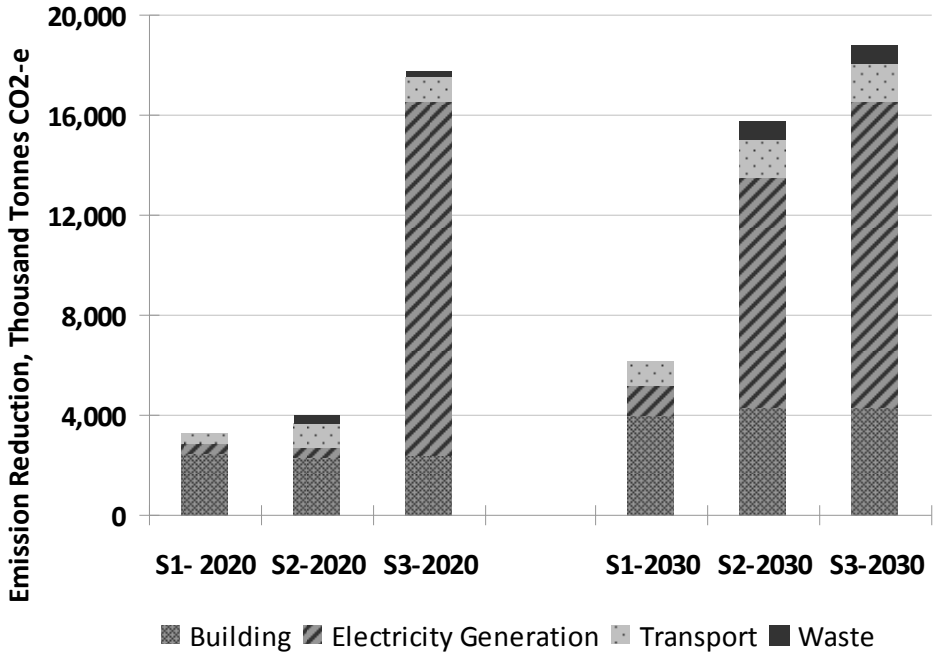
This section evaluates the carbon abatement potentials in particular sectors (i.e. building, transport, electricity generation, and waste) for all three alternative scenarios. This is achieved by performing a static comparative analysis on the MARKAL Model results obtained under partial equilibrium of

(1) The air emission reductions in Scenario 1 are not directly comparable with those in the AQO study due to several factors including 1) different modelling approaches were adopted; 2) the AQO study assumes 50% nuclear and 50% natural gas will be used to generate electricity by 2030, which is different from the assumptions in Scenario 1.

the energy market. Carbon emissions and associated energy system costs for each sector in all three scenarios are compared to the Base Case to evaluate each sector's abatement potential.

Figure 3.5 presents the carbon emission reduction potentials in 2020 and 2030 for Scenarios 1, 2 and 3 relative to the Base Case.

Figure 3.5 Carbon Abatement Potential by Sector by Scenario (Tonne CO_2-e)



It is important to note that the abatement potentials calculated for each sector are not to be used to estimate the total system abatement potential. This is due to the fact that static comparative analysis does not catch the potential offsets (or synergies) among sectors and various sub-sectors. For example, a reduction in electricity demand in the buildings sector also reduces the size of the electricity market and hence, the abatement potential of the supply group. Another limitation of the static comparative analysis arises from that fact that mitigation measures in one sector may require the synergy provided from measures in another sector. For example, in the transportation sector in Scenario 3, the measures to switch all passenger cars and taxis to electric vehicles would increase electricity supply. This increase would result in a net increase in carbon emissions unless it is met by renewable or imported nuclear electricity instead of the gas combined cycles (a synergy required from the supply sector).

3.4.6 Limitations and Challenges of the HKMM Modelling Methodology

The HKMM model developed for this study represents the detailed energy and environmental system of the HKSAR, which facilitates the evaluation of GHG abatement potentials under various mitigation scenarios. The model measures the impact of alternative energy system development pathways determined under each scenario on economic growth, in terms of GDP

changes. Even though the model's results and analysis presented in this section exhibit its diverse capability in achieving the objectives of the study, there are limitations and challenges to the approach that need further attention to refine and expand its current structure/approach. We outline the main limitations and challenges below.

- The current structure of HKMM confines the analysis of GHG mitigation impacts strictly within the Hong Kong SAR. A better coordination of joint analysis and implementation of these measures can be accomplished in a multi-regional MARKAL model framework.

- The embodied energy and GHG that are crucial to the manufacture and transportation of various consumer and industrial products and materials (eg cement) imported to the HKSAR are not considered in the HKMM. Additional mitigation measures (eg imports of green products and conservation of material use) need to be addressed to expand the abatement potential in Hong Kong SAR and beyond.

- Not all economic benefits can be reflected in the Model. For instance, green jobs can be created when renewable energy plants are built, but it is difficult to quantify and forecast the associated economic benefit. Also, the assessment doesn't quantify the energy reduction potential from changes of consumer habits.

- The impact of mitigation measures on consumer inflation and business costs is not quantified in the Model. In the short and medium term, inflation and business costs may be affected by the energy prices and investment costs. However, they are also influenced by a variety of factors such as relative elasticity of wages, interest rates, and growth rate of money supply.

- Normal climate conditions were assumed in the energy use projection. Should the prevailing temperatures change as a consequence of climate changes, the final energy demand might be different. For example, higher temperatures implies higher energy demands for cooling and hence an increase in carbon emissions.

- The assumptions and model outputs are not accurate projections for the future. The purpose of the Study is to assess the impacts of various mitigation measures and scenarios on GHG emission abatements. Measures and assumptions in mitigation scenarios are based on international technology and policy review. They are not implementation targets, but provide an envelope within which the impacts of alternative assumptions can be inferred. Detailed feasibility studies for individual measures are required at later stages.

3.5 SCENARIO 3 MEASURES AND POSSIBLE PROGRESS

To deliver a substantive reduction in carbon intensity, implementing Scenario 3 is preferred. As compared with other Scenarios, Scenario 3 could also deliver substantive reduction in GHG emissions in absolute terms between 2005 and 2020 and would deliver more GHG reduction than Scenario 2 by 2030. *Table 3.9* presents key measures to support the achievement of carbon intensity reduction under Scenario 3 and possible progress of these measures by 2020 and 2030.

Meeting the predicted levels of reduction in carbon intensity and GHG emissions under Scenario 3 by 2020 will require a significant and rapid rebalancing of the fuel mix in the electricity sector and associated investments in the transmission infrastructure. Given the time needed to plan and construct such infrastructure, as well as securing energy supplies, early adoption of these measures is required to deliver the 2020 national target. Accelerating the pace of energy efficiency gains is also necessary and will require support and participation from all sectors of the economy, as well as a favourable economic environment.

Table 3.9 Key Measures to Support Achievement of Carbon Intensity Reduction under Scenario 3 and the Possible Progress of these Measures by 2020 and 2030

Measures	**Scenario 3**		
Buildings and Appliances (1)	**2020**		**2030**
Expanding the scope and tighten the requirements of the Building Energy Codes (BEC)	Up to 50% energy saving of major installations in all new commercial buildings		Up to 50% energy saving of major installations in all new commercial buildings
Expanding the use of district cooling system (DCS)/water-cooled air conditioning system (WACS)	Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners		All commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners
Reducing energy demand in new buildings through e.g. tightening the overall thermal transfer value (OTTV) standards and promoting wider adoption of green roofing	Up to 50% cooling demand reduction in all new commercial buildings		Up to 50% cooling demand reduction in all new commercial buildings
Expanding the scope and tightening the energy efficient electrical appliance standards for domestic use	Appliances sold in the market in 2020 will be up to 25% more energy efficient, compared with 2005 level		Appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level
Improving energy efficiency through good housekeeping, information technology products or intelligent Building Environmental Management System	Up to 15% Energy efficiency improvement in up to 25% of existing commercial buildings		Up to 15% energy efficiency improvement in all existing commercial buildings
Transport			
Wider use of motor vehicles running on alternative fuel	Hybrid/EV or other vehicles with similar performance: 30% private cars, 15% buses, 15% goods vehicles		Hybrid/EV or other vehicles with similar performance: 50% private cars, 50% buses, 50% HGV and LGV
Petrol blended with 10% Ethanol (E10)	All petrol to be blended with 10% of ethanol		Same as 2020
Diesel blended with 10% Biodiesel (B10)	All diesel to be blended with 10% of biodiesel		Same as 2020
Implementation of importers' average fleet efficiency standards	New vehicles will be 20% more energy efficient than the 2005 market average		Same as 2020
Waste			
Construction and operation of waste-to-energy facilities	One IWMF with a treatment capacity of 3,000 tonnes/day; two OWTFs operating at a total capacity of 400 tonnes per day		Sufficient IWMFs to treat all MSW in HK; two OWTFs operating at a total capacity of 400 tonnes per day
Utilization of landfill gas as energy source	Full utilization of recovered landfill gas		Full utilization of recovered landfill gas
Utilization of gas generated from wastewater treatment	Full utilization		Full utilization
Utilization of sludge treatment with energy recovery	One sludge treatment facility operating at full capacity		One sludge treatment facility operating at full capacity
Energy Supply	**2005**	**2020**	**2030**
Use of coal in electricity generation	ca 50%	≤10%	0%
Use of natural gas in electricity generation	ca 25%	ca 40%	ca 50%
Import of nuclear generated electricity	ca 25%	ca 50%	ca 50%
Renewable energy (RE) (2)	<1%	3% to 4%	3% to 4%

Notes:

(1) The purpose of the Study is to assess the impacts of various mitigation measures and scenarios on GHG emission abatements. Measures and assumptions in mitigation scenarios are based on international technology and policy reviews. They are not implementation targets, but provide an envelope within which the impacts of alternative assumptions can be inferred. Detailed feasibility studies for individual measures are required at later stages, taking into account limitations, uncertainties and practicability of the measures within Hong Kong's local context.

(2) RE includes wind energy, and energy recovered from landfill gas (LFG), Integrated Waste Management Facilities (IWMF) and Organic Waste Treatment Facilities (OWTF).

4.1 BACKGROUND

Atmospheric carbon dioxide (CO_2) has been maintained, by the carbon cycle, at 200 to 300 parts per million (ppm) over the last 400,000 years (1), and at 260–280 ppm for the 10,000 years between the end of the last glacial maximum and the start of the industrial era c.1750 (2). Human activities have interfered with this balance since the 1700s by releasing greenhouse gases (GHGs) into the atmosphere through a variety of activities including: the combustion of fossil fuels, land-use changes, agricultural activities and the use of CFCs in refrigeration systems.

The current atmospheric CO_2 concentration is 387ppm (3), up almost 40% since the industrial revolution and the highest for at least the last 650,000 years. Observations indicate that this atmospheric concentration is increasing every year (*Figure 4.1*), similar to the other GHGs.

At present, about 49 billion tonnes of GHGs is emitted globally each year (4), mostly through the combustion of coal, oil and gas for energy. Between 1970 and 2004, global emissions of GHGs, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), weighted by their global warming potential (GWP), have increased by 70% (5) (24% between 1990 and 2004) (6). By 2030, atmospheric concentrations of CO_2 are likely to be 60% higher than they would be without human interference (7).

(1) Mayor of London, 2008: The London Climate Change Adaptation Strategy. Draft Report (August 2008).

(2) Denman, K.L., G. Brasseur, A. Chidthaisong, P. Ciais, P.M. Cox, R.E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U. Lohmann, S Ramachandran, P.L. da Silva Dias, S.C. Wofsy and X. Zhang, 2007: Couplings Between Changes in the Climate System and Biogeochemistry. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

(3) NOAA, Mauna Loa Observatory carbon dioxide dataset. Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/)

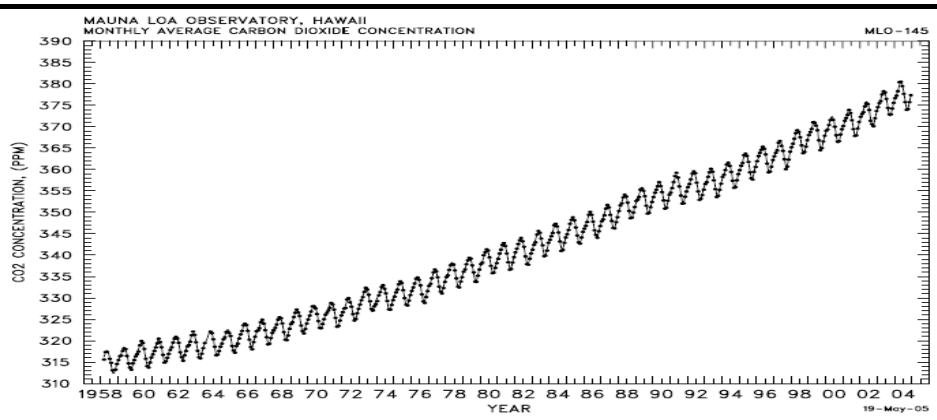
(4) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.), IPCC, Geneva, Switzerland.

(5) Weighted by their global warming potential (GWP)

(6) IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marqu

(7) Dupont, Alan. and Pearman, Graeme, 2006: Heating up the Planet – Climate Change and Security, Sydney Lowy Institute, 143 pp.

Figure 4.1 Recent Historic Atmospheric CO_2 Concentrations



Source: Keeling and Whorf, 2005 (1)

According to the Fourth Assessment Report (AR4) of the IPCC, during the past century the global average temperatures have risen by 0.74 °C between 1906 and 2005 (100-year linear trend). For the next two decades, 0.2 °C of warming per decade is projected. AR4 also assessed that even under the most optimistic climate modelling scenarios the average global temperature will rise by 1.8°C to 4.0°C by 2100. Sea level rise is another anticipated impact resulting from climate change. AR4 reports that satellite data show that the global average sea level has risen at 1.8mm per annum since 1961 and at 3.1 mm per annum since 1993.

4.2 *CLIMATE CHANGE IN HONG KONG*

A climate change vulnerability assessment for Hong Kong has been carried out using scenarios that are based upon the science in the IPCC AR4 and publications by the Hong Kong Observatory (HKO). HKO began making systematic observations of climatic variables more than 120 years ago. There are observable changes in many weather patterns, including many key impacts that have been observed within the last 60 years, which also correspond to the changes experienced by many global climatic systems observed over the same period.

Climate change will exert many, albeit very different, impacts, on various sectors and sub-sectors of the Hong Kong economy. *Tables 4.1* and *4.2* summarise some of the major observed climatic changes in Hong Kong and the key impacts of projected future climate change scenarios, respectively.

(1) Keeling, C.D., and T.P. Whorf, 2005: Atmospheric CO2 records from sites in the SIO air sampling network. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy

Table 4.1 Observed Climate Changes in Hong Kong (HKO)

Variable	Observed Change
Annual mean temperature	+0.12 °C per decade (1885-2009)
Mean diurnal range	-0.24 °C per decade (1947-2009)
Hot nights (minimum temperature ≥ 28 °C) in June - August	+3.5 nights per decade (1947-2009)
Cold days (minimum temperature ≤ 12 °C) in December - February	-2.3 days per decade (1948-2009)
Annual rainfall	+51 mm per decade (1947-2009)
Thunderstorms days	+1.8 days per decade (1947-2009)
Heavy rain days (hourly rainfall > 30 mm)	+0.4 days per decade (1947-2009)
Mean sea level (Victoria Harbour)	+26 mm per decade (1954-2009)

Table 4.2 Projected Change in Climatic Factors by 2100 (HKO)

Variable	Current Conditions	Impact	Lower Bound	Upper Bound	Level of Confidence
Decadal mean annual temperature	23.1 °C	27.9 °C	24.5 °C	32.3 °C	High
Hot nights in June - August	12.2	41.2	22.0	68.7	Medium to Low
Very hot days (maximum temperature ≥ 33 °C) in June – August	8.2	15.3	9.6	23.5	Medium to Low
Cold days in December - February	16.3	<1	<1	<1	Medium to Low
Annual rainfall (mm)	2383	2572	1763	3235	Low
Heavy rain days	6.1	6.5(*)	2.5(*)	8.3(*)	Low
Years with annual rainfall < 1282 mm	2(#)	3.6(+)	Not defined	Not defined	Low

Notes:
Unless otherwise specified, the reference period for current conditions is 1971-2000 while that for impact, lower/upper bound is 2090-2099.
*: 2070-2099
#: 1885-2008
+: 2010-2099
Projected figures may be revised as scientific data and information are updated.

4.3 UNCERTAINTIES IN CLIMATE CHANGE SCIENCE

The subject of climate change is relatively new and the science is constantly evolving. There are considerable scientific uncertainties associated with lack of information and disagreement about what is known or even knowable embedded in the current state of climate change science. It is worth noting that climate *projections* should not be misinterpreted as climate *predictions*. The scientific community adopts the term *projections* (and not *predictions*) when describing future changes in climate as *projections* involve assumptions in parameters, e.g. future socio-economic and technological developments, and are therefore subject to substantial uncertainty.

The IPCC AR4 currently represents the best available international consensus on the likely impacts of climate change, upon which the current vulnerability analysis for Hong Kong is based. Nonetheless, ERM has noted areas where the risks are such that a watching brief needs to be maintained on the latest science to ensure that appropriate responses are developed. These include(1):

- "Real World" Environmental Uncertainty; Inherent and Natural Internal Variability: natural external factors (e.g. solar output, volcanic activity) or future choices made by societies.
- Data Uncertainty: e.g. measurement error, incomplete or insufficient data due to limited temporal and spatial resolution, extrapolation based on uncertain data.
- Knowledge Uncertainty: e.g. lack of knowledge regarding future emissions, uncertainties about sea level rise.
- Model Uncertainty: e.g. model choice and structure, model input values, model parameters or model output variables and values

Uncertainties may arise from a variety of sources and ranking or estimating their magnitude often relies on expert, subjective judgement. Therefore, any climate change adaptation strategies should be flexible enough to be effective in the context of a degree of uncertainty and be able to accommodate and assimilate new evidence as it arises.

4.4 HONG KONG CLIMATE CHANGE VULNERABILITY ASSESSMENT

4.4.1 Sector Coverage

The vulnerability of following sectors of Hong Kong to climate change was assessed in this Study:

- Agriculture
- Aquaculture
- Biodiversity and Nature Conservation
- Built Environment and Infrastructure
- Business and Industry
- Energy Supply
- Financial Services
- Food Resources
- Human Health
- Leisure and Tourism
- Water Resources

(1) Willows, R.I., and R.K. Connell, (Eds.), 2003: Climate adaptation: Risk, uncertainty and decision-making. UKCIP Technical Report. UKCIP, Oxford.

4.4.2 *Framework for Vulnerability Assessment*

A framework based upon best practice identified through an international literature review was used for assessing the vulnerability for each of the sectors and associated systems (i.e. sub-sectors), and hence the determination of key vulnerable sectors. The framework of this assessment involves four main stages:

1. Exposure and Sensitivity Analysis

This stage identified the exposure (i.e. the background climate conditions and their changes) that could impact on systems/receptors in each of the sectors as well as the sensitivity of the systems/receptors to such exposures. Climate change scenarios developed from local studies by the HKO and international studies such as the IPCC AR4 were used for this assessment. The assessment included a review of the level of confidence with respect to the exposure and sensitivity of the sector in Hong Kong as well as identifying the sources of such uncertainties.

2. Identification of Potential Consequences

This stage identified the potential consequences of the exposure and sensitivities identified under stage 1, i.e. who and what will be affected, as well as the level of confidence in such assessment and the source of associated uncertainties.

3. Climate Change Impacts and Vulnerability Assessment

This stage provided an overview of how vulnerable each system/receptor was to the potential impacts associated with the changing climate, i.e. how exposed is this system to the impact, how sensitive are they to the change, and what is their capacity to adapt.

4. Selecting 'Key' Vulnerabilities

Based upon the preceding stages ERM identified key vulnerable sectors in Hong Kong. Some of the criteria / elements that were considered when identifying key vulnerabilities include magnitude, timing, persistence and reversibility of impacts, likelihood of impacts and vulnerabilities, and confidence in those estimates, potential for adaptation, distributional aspects of impacts and vulnerabilities, and importance of the vulnerable system(s) to Hong Kong.

4.4.3 *Uncertainties and Limitations of Vulnerability Assessment*

This is the first comprehensive assessment of vulnerability to climate change in Hong Kong. It has been carried out based upon the current state of knowledge and the information available in the IPCC AR4 as well as consultant's and health expert's judgments so as to make an assessment of the potential areas of greatest risk. It should be acknowledged that the quality and quantity of information available to make the assessment vary between

systems. Moreover, there are uncertainties and limitations associated with the information in AR4 and hence the outcome of the vulnerability assessment. For instance, there is higher uncertainty in how biodiversity will respond to changing climatic conditions when compared to some other highly managed systems such as the built environment and infrastructure. Where there is a lack of "local" scientific data to support the research-driven approach to assess the vulnerability and adaptation of a particular sector, ERM has exercised expert judgement to determine the risk rankings of this sector, for example, the risk rankings under Human Health sector.

At the time of preparing this report, IPCC is preparing the Fifth Assessment Report (AR5) due for publication in 2015. Much work is being undertaken, including the development of new scenarios for impacts, adaptation and vulnerability (IAV) assessments. With the rapid evolution in the climate change science, the vulnerability assessment should be considered as a dynamic process and the findings of the assessment should be regularly reviewed and updated, particularly given the high-levels of uncertainty inherent in an exercise of this nature. It should be noted that this vulnerability assessment provides a high-level "screening" of the key vulnerabilities that are currently considered critical.

4.5 KEY VULNERABILITIES IN HONG KONG

Based on the future climate scenario outlined in *Table 4.2*, an assessment was undertaken to identify the key sectoral vulnerabilities. Eight key sectors were identified as having a "high" vulnerability to climate change impacts, namely: Biodiversity and Nature Conservation; Built Environment and Infrastructure; Business and Industry; Energy Supply; Financial Services; Food Resources; Human Health, and Water Resources. Examples of projected impacts to key vulnerable sectors are summarised in *Table 4.3*. Further description of projected impacts is provided in *Appendix C*.

Table 4.3 Examples of Projected Impacts for 'Key' Vulnerable Sectors

'Key' Vulnerable Sectors	Examples of Projected Impacts
Biodiversity and Nature Conservation	• Climate change can increase loss of biodiversity and increase colonisation of invasive species • Damage to woodlands, coral communities due to increase in frequency and/or severity of extreme weather • Change in species distribution patterns due to increase in surface temperatures
Built Environment and Infrastructure	• Very high uncertainties in the magnitude and rate of sea level rise • Developments located on low-lying areas / reclaimed land are highly sensitive to climate change • Heavy rain, thunderstorm and extreme weather leading to the damage of building foundations, increased risk of rain penetration o building fabric, and damage to utilities cabling and pipes • Potential asset damage because of flooding, landslides, wind damage, storm surge, and lightning strike, etc.

'Key' Vulnerable Sectors	Examples of Projected Impacts
Business and Industry	• Heavy reliance on international trade, financial markets, imports of key products and services exposing Hong Kong to climate change impacts beyond its boundaries and increasing its vulnerability • Vulnerable to climate change impacts on other areas such as food and water resources, transportation and infrastructure, etc. • Higher insurance costs
Energy Supply	• Interruptions in power supply are likely to result in economic and social costs. Also, electricity generation, supply and primary energy supply are vulnerable to climatic disruptions • High uncertainties in impacts along the supply chain and effects of warmer climate • Increased demand from air conditioning and refrigeration due to increase in surface temperatures leading to supply interruptions and power spikes • Risk of flooding, lightning strike, landslides, causing damage to power lines and other assets
Financial Services	• Direct risk relating to vulnerability of telecommunications and computer systems to storms, power failure and spikes • Indirect exposure in terms of changes to the risk profile of individual business and their investments • Some segments of financial services likely to be more exposed, e.g. insurance • Sector may be vulnerable to impacts on other areas i.e. infrastructure
Food Resources	Extreme weather reducing agricultural outputs at sources of food imported to Hong Kong and pushing up commodity prices Rise in temperature and increased incidence of pests and diseases affecting poultry and livestock species and resulting in more expensive and lower availability of imports
Human Health	• Climate change expected to disproportionately affect vulnerable groups • Chronic health conditions such as cardio-vascular and respiratory diseases may be aggravated by climatic variables • Thermal stress, exacerbation of asthma and heat stroke may be caused directly by climatic variables • More accidents and emergency situations may result from increased frequency and/or intensity of extreme weather, such as storms, floods, droughts and tropical cyclones, etc. • Changes in some infectious disease transmission patterns are a likely consequence of climate change
Water Resources	Uncertainties in future rainfall levels could affect water availability Water availability may be constrained by physical or contractual reasons Changing distribution pattern of rainfall and rising regional demand for freshwater may impact on the sustainability of water supply Increased consumer demand for water due to increase in surface temperatures Possible salinization of freshwater aquifers due to sea level rise

Their vulnerability is due to a number of factors including:

- Broad geographical exposure, i.e. they are highly depending on imports such that they are vulnerable to potential climate change impact not only in Hong Kong but also in other parts of the world.

- High sensitivity to climatic factors, i.e. they are dependant upon a stable climate over time or designed to operate/function within a small window of climatic variation.

- The consequences of disruption to these sectors are also high, i.e. many socio-economic activities of Hong Kong are relying on the products / services provided by these sectors.

- Broad temporal exposure, i.e. investment / infrastructure decisions in these sectors require a long lead time.

- Reliance upon extended infrastructure with multiple potential failure points, i.e. they are building on an extensive infrastructure in which there may be many potential areas to fail under the impact of climate change.

- Complex inter-relationships with other sectors, i.e. they are widely connected with other sectors in the community.

- Failure to cope with extreme weather events occurring today, e.g. on 7 June 2008 Hong Kong was affected by heavy rainstorms and squally thunderstorms, resulting in the blockage of North Lantau Highway by landslides for the first time since the commencement of operation in 1997, and serious disruption in transportation, water supply and telecommunication to Tai O by landslides, and serious flooding in various parts of Hong Kong. Furthermore, there was a sea flooding incident of Tai O during the passage typhoon Hagupit in September 2008.

4.6 EXTANT ADAPTIVE CAPACITY IN HONG KONG

As with other cities in the world, Hong Kong is vulnerable to climate change because of the agglomeration of people and assets in a small area. Hong Kong's vulnerability is compounded by its dependence on imported food, water, energy and other products that are required for it to thrive. Hong Kong, however, possesses significant adaptive capacity and has many systems in place which could be used to adapt to the physical impacts of climate change, examples include the following.

- With regards to the emergency response, the Security Bureau (SB) co-ordinates the planning of Government's overall response to major emergencies. The Government has developed the "Emergency Response System" and "Contingency Plan for Natural Disasters" to respond to the emergency situations and handle the natural disasters (including those results from severe weather conditions). When there is an emergency or natural disaster, the Government will trigger these systems such that the

emergency response measures can be implemented speedily and efficiently. The Emergency Monitoring and Support Centre (EMSC) is activated when major emergencies or natural disasters happen or are likely to happen. It monitors the response of the emergency and support services, and provides support to these services and takes appropriate actions during Rescue, Recovery and Restoration Phases.

- Various government departments and public utilities service providers have monitoring and emergency responses mechanisms in place to respond to certain climate change impacts, including

- The Geotechnical Engineering Office (GEO) of Civil Engineering and Development Department (CEDD), in consultation with HKO, issue Landslip Warnings when numerous landslips are expected to alert the public as well as relevant parties so that they can take necessary precautions to ensure safety.

- The GEO recently launched the Landslip Prevention and Mitigation Programme (LPMitP) to dovetail with the Landslip Preventive Measures (LPM) Programme which was completed in April 2010.

- Drainage Services Department (DSD) has operated the Emergency and Storm Damage Organisation to ensure that floods and other emergency situations could be dealt with speedily. When Red or Black Rainstorm Warning or Typhoon Warning Signal No. 8 or above is issued, the Emergency Control Centre will put into operation immediately. Also, DSD will closely monitor the water levels of river streams and flooding conditions of flood prone areas in Hong Kong and work with HKO and Home Affairs Department (HAD) to remind the residents living at coastal and low-lying areas about the flood risks resulting from the rainstorms.

- Buildings Department (BD) will activate the Emergency Control Centre when Tropical Cyclone Warning Signal No. 8 is issued or in times of heavy rainfall and other disasters. It co-ordinates professional services to deal with dangerous buildings, landslides, dangerous scaffolding and advertising signs.

- The Hong Kong Monetary Authority (HKMA) has established an emergency response plan to handle the issues that will affect banking stability in Hong Kong. HKMA anticipates that emergency response plans will also be developed by the banking institutions in order to ensure their normal operation. Such response plans will normally form part of the organisation's continuity plan and it will include arrangements for backup services and methodology for service reactivation.

- The Office of the Telecommunications Authority (OFTA) has an emergency response team that operates throughout the year and maintains close contacts with the telecommunications operators, relevant governments and overseas bodies so as to obtain the latest information

about the emergencies (including the incidents resulting from the extreme weather events).

- The Transport Department (TD) has established the Emergency Transport Co-ordination Centre (ETCC) to closely monitor the traffic and public transport services throughout the year. The centre also has developed contingency plans for the traffic and public transport service disruption due to extreme weather events such as typhoons, rainstorms, flooding and landslides, etc. and coordinates with various Government departments such as Hong Kong Police Force (HKPF), Highways Department (HyD) and public transport service providers to implement the contingency plans and to disseminate the contingency measures and real time traffic conditions to the public through mass media.

- The power companies have developed emergency response plans to handle the issues on power systems (e.g. power outage) due to bad weather. These plans are subject to periodic review by the power companies and the Government is monitoring it through legislative means.

- According to the Reserved Commodities Ordinance and its subsidiary Regulations (Cap. 296), rice is classified as a reserved commodity under the regulation. The Government operates the Rice Control Scheme to ensure a stable supply of rice and the stockholders have to keep a reserve stock sufficient for consumption by the population for a reasonable period (at present 15 days) to cater for emergencies or any short term shortage of supply. About 70% of wheat flour is imported from Mainland China. The Trade and Industry Department (T&ID) monitors the import quantity of wheat flour periodically and will liaise with relevant authorities in Mainland China to increase the supply quantity if necessary.

- The Works Departments developed guidelines in 1990, in which relevant government works projects should consider the rate of mean sea level rise may increase at 10 mm per year so as to address the potential impacts from climate change.

- In the event of a Typhoon signal No. 8 or above, a landslip warning or a Red or Black rainstorm warning, Home Affairs Department and the Department Emergency Co-ordination Centre (DECC) will be activated for the provision of emergency support services. An emergency hotline manned round the clock for the provision of weather reports, information and assistance to the public will also be available. Temporary shelters to people in need in event of cold or prolonged hot weather are also provided. Meals, blankets and mattresses are provided to shelter-seekers at a number of widely-publicized locations.

- In view of the climate change impacts and potential increase of extreme events in the coming years, HKO periodically review the Tropical Cyclone, Rainstorm and Very Hot Weather Warning systems so as to fulfil the needs of the society and citizens.

- The Centre for Health Protection (CHP) and Central Health Education Unit (CHEU) of the Department of Health (DH) provides health advice in relation to climate change, such as advice to the elderly in extreme weather (heat/cold stress).

- The Labour Department (LD) has a Code of Practice that seeks to provide advice and practical guidelines on work arrangements in times of typhoons and rainstorms, in particular when Typhoon Warning Signal No. 8 or above or Black Rainstorm Warning is in force (e.g. Guide on Safety at Work in times of Inclement Weather, Code of Practice in times of Typhoons and Rainstorms). With regards to prevent heat stroke at work, LD has developed guidance, including Prevention of Heat Stroke at Work in a Hot Environment, Risk Assessment for the Prevention of Heat Stroke at Work, to raise the awareness of the employers and employees about heat stroke and instil them with practical skills to prevent heat stroke.

- Various programmes are in place to monitor certain climate change impacts on various species and resources, including

- The Agriculture, Fisheries and Conservation Department (AFCD), through its territory-wide survey programme, is identifying and monitoring the important components of biological diversity in Hong Kong. The information collated from the programme is used to study the climate change impacts to the flora and fauna species in Hong Kong. Through the Baseline Ecological Monitoring Programme and Waterbirds Survey at Mai Po Inner Deep Bay Ramsar Site, AFCD monitors and conserves the ecological value of this important wetland.

- The Department of Health (DH) coordinates the public health information and disease surveillance system in order to monitor the communicable diseases and collate the epidemiological data. Also, DH maintains close contact with Food and Environmental Hygiene Department (FEHD) so as to obtain the climate related vector-based data (e.g. Ovitrap Index) and food safety monitoring information from FEHD and take appropriate remedial measures accordingly.

- The Water Supplies Department (WSD) is implementing Total Water Management Programme and one of the objectives of the programme is to prepare for the changes brought on by climate change and potential reduction of rainfall. WSD periodically reviews and continuously monitors the water resources in Hong Kong and take appropriate actions to ensure the stable supply of water to Hong Kong society.

- AFCD monitors the supply and wholesale price of major food items and provides the information to the public periodically for reference. Also, AFCD strives to increase the sources of food supply and diversify the types of food so as to ensure the stable supply of food to Hong Kong.

- The Centre for Food Safety (CFS) of FEHD carries out risk assessment, risk management and risk communication to ensure food safety in Hong Kong, including research on food safety topics that are important to public health, food surveillance and sampling at the import, wholesale and retail levels, import control on high risk food items, monitor the food safety incidents in and outside Hong Kong through the Food Incidents Monitoring Mechanism and communicate with the trade and public about the food safety issues.

- In addition to the mandatory *Third Party Risks Insurance*, building owners and owners' corporations are advised to purchase *Property-All-Risks Insurance* (property insurance), which covers losses or damages to the common properties of the building due to fire or other risks e.g. flooding.

- The Hong Kong Exchanges and Clearing Limited (HKEx) has developed procedures and guidance for emergencies, including the exchanges and clearing arrangements under Typhoon and Black rainstorm as well as the exchanges and clearing rules and process for various HKEx departments.

- The Education Bureau (EDB) has held workshops aimed at improving teachers' understanding of climate change, and climate change is included in the curriculum. The HKO has provided an educational package for distribution in schools that aims to raise awareness and understanding of climate change and the associated impacts. AFCD has carried out a series of education programmes at Hong Kong Wetland Park, including seminars and bird watching competition, to encourage public participation in wetland conservation.

- There are a number of policies and measures, mainly implemented by the AFCD to protect and conserve biodiversity. There are measures that aim to protect endangered species of animals and plants by regulating all activities involving the listed species, to protect wild animals from human disturbances as well as conservation programmes for species that are of ecological importance, such as the Chinese White Dolphin.

- The Drainage Services Department (DSD) implements flood prevention projects (including eight Stormwater Drainage Master Plan (DMP) Studies) to improve the drainage systems for the whole territory, in particular in the low-lying flood plains of the North and Northwest New Territories, to relieve flooding problems and to raise the flood protection level.

It is, however, likely that some such policies may need to be enhanced, or that the climatic thresholds which trigger other policies may need to be made more conservative. Furthermore, the resources allocated to the implementation of policies and measures to protect and respond to climatic events may need to be increased to better respond to climate change. The following sections present the options identified to ensure that any such necessary changes can take place in a timely manner.

4.7 PROPOSED ADAPTATION OPTIONS

Based on the findings of vulnerability assessment, it is evident that several sectors in Hong Kong are vulnerable to climate change impacts. Therefore, adaptation measures, including available options, should be developed to minimise the risk brought about by climate change.

4.7.1 *Approach to Developing Climate Change Adaptation Options for Hong Kong*

The identification of climate change adaptation options for Hong Kong was based upon the following:

- General principles of international best practice (tenets of which include 'Sustainable', 'Inclusive', 'Flexible and regularly revised', 'Pro-active', 'Based upon the precautionary principle');
- A comprehensive review of overseas adaptation policies and measures, which included initiatives at the national, sub-national (i.e. jurisdictions in federally organised countries) and municipal levels; and,
- A detailed review of existing institutions in Hong Kong, i.e. legislative policies and measures currently in place in the public sector which offer adaptive resilience.

4.7.2 *Framework for Adapting to Climate Change in Hong Kong*

A review of existing adaptation policies and measures adopted in Hong Kong as well as other world cities, including London, Singapore, Tokyo and New York City, was performed and identified the following recommended government frameworks for adapting to climate change.

- Sectoral-level actions in the eight most vulnerable sectors identified for Hong Kong.
- Cross-sectoral activities such as research activities to inform government decision making and activities to raise awareness of Hong Kong's vulnerabilities to climatic change, as well as possible adaptation actions to address them.
- Cross-departmental bodies to monitor and co-ordinate government action to ensure consistency across government decision-making.

The following sections highlight the proposed adaptation options for Hong Kong. It should be noted that the options presented in this Report are based upon current understanding of climate change projections and will need to be periodically reviewed and updated as the science evolves. IPCC is preparing its AR5 due for publication in 2015. More detailed analysis on the possible impacts of climate change on different sectors would then be available and hence new or updated adaptation strategies should be developed based on the updated findings. Moreover, implementation of proposed adaptation options is likely to lead to additional compliance costs to both the Government

and the other concerned stakeholders. Hence, the implications, feasibility and costs and benefits of these measures should be evaluated before adoption.

4.7.3 Major Categories of Sectoral-Level Adaptation Options

The sectoral-level climate change adaptation options can be classified into the following major categories:

- **Research & investigation –** efforts to expand current knowledge regarding vulnerable sectors is needed in a number of areas and includes: establishing priorities for improvement measures, identifying local high risk areas, updating outdated information, assess and examine potential impacts and effects.

- **Monitoring –** creation of monitoring infrastructure which enhances knowledge pertaining to the status of key sectors, as well as enhancement of current efforts for the purpose of reviewing and revising current programs. Such measures could include periodic review of monitoring programmes, observe and closely track changes in economic, environmental and social indicators.

- **Institutional strengthening & capacity building –** enhance the ability of institutions to respond and adapt to adverse impacts brought about by climatic changes. Such strengthening could include: incorporating climate change knowledge into current management framework, assess potential risks and opportunities in development strategies, outline potential impacts on the operations of key sectors.

- **Disaster management & emergency planning –** improvement of the planning and systems which are responsible for responding to emergencies. Such enhancements could include: mandating emergency planning measures, development of contingency plans and reviewing current disaster monitoring and response systems.

- **Education & public awareness –** increase the level of public awareness amongst the population such that they can take appropriate actions to combat climate change impacts. This could include promotion of climate change impact assessments and knowledge, providing information on the likely implications of climate change on various industries and sectors, and educating vulnerable communities on how best to prepare and respond to climate change.

Table 4.4 highlights some sectoral-level adaptation options that the SAR Government and relevant stakeholders in Hong Kong could take.

Table 4.4 *Examples of Climate Change Adaptation Options for Key Vulnerable Sectors in Hong Kong*

Category of Adaptation Options	Key Vulnerable Sectors	Examples of Proposed Adaptation Options
(a) Research & Investigation	• Biodiversity and Nature Conservation	• To establish priorities for species/ habitats/ ecosystems most at risk • To develop a baseline of species, especially for those of conservation importance
	• Built Environment and Infrastructure	• To identify at-risk infrastructure that are likely to be vulnerable to climate impacts • To update flood risk maps
	• Financial Services	• To examine the potential for expanding the role of insurers in climate risk management, examine legal roles of insurance industry • To examine the insurance coverage on climate risks for infrastructure and assets located in hazard-prone areas and vulnerable assets, and the legal implications of the insurance industry in dealing with climate risks
	• Food Resources	• To examine the impacts on food supply chain and food hazards, and research effects on vulnerable groups
	• Human Health	• To research health and nutrition effects on vulnerable groups
	• Water Resources	• To assess the impacts along the water supply chain
(b) Monitoring	• Biodiversity and Nature Conservation	• To review and revise monitoring programmes periodically
	• Energy Supply	• To monitor for changes in energy demand and supply patterns to identify trends caused by climate change
	• Food Resources	• To monitor prices of major food stuff and factors that could lead to fluctuations in prices, and climate change agricultural impact studies for Hong Kong's key food importers

Category of Adaptation Options	Key Vulnerable Sectors	Examples of Proposed Adaptation Options
	• Human Health	• To set up monitoring programmes to observe health and food safety implications of extreme temperatures on local population and associated impacts on different groups of population • To set up monitoring programmes on proliferation of pests with public health significance
(c) Institutional Strengthening and Capacity Building	• Built Environment and Infrastructure	• To develop and use climate risk assessment tool for screening future development projects to minimise potential risks posed by climate change and variability • To regularly update and adjust, if necessary, construction-related codes, guidelines and design standards for buildings and infrastructure • To develop flood and landslip risk strategies for increasing adaptive capacity to extreme weather and sea level rise
	• Business and Industry	• To develop a Hong Kong business assessment tool for climate change impacts
	• Energy Supply	• To review likely changes in energy demand and supply patterns periodically • Power companies to consider the latest available climate change scenarios and associated impacts during regular review and forecasts of energy demand and supply • To diversify fuel sources and fuel suppliers • To assess and act on the climate risks and challenges along the energy supply chain, including those at fuel sources and associated logistics and at the generation and distribution assets themselves
	• Financial Services	• To encourage companies to disclose to regulators/investors the financial risks from climate change, and actions being taken to respond to those risks
	• Food Resources	• To allocate responsibility for security of food supply

Category of Adaptation Options	Key Vulnerable Sectors	Examples of Proposed Adaptation Options
	• Water resources	• To consider climate change and variability in the regional context and their impact on water resources • To periodically review HK's Total Water Management Strategy
(d) Education and Public Awareness	• Built Environment and Infrastructure	• To promote green roofs
	• Business and Industry	• To promote business climate impact assessments
	• Financial Services	• To examine the implications on the insurance and banking industries by engaging them to consider risks and opportunities with climate change through awareness raising
	• Food Resources	• To encourage business continuity planning
	• Human Health	• To educate the medical community on
	• Water Resources	• To promote water conservation
(e) Disaster Management & Emergency Planning	• Business and Industry	• To request essential operations to prepare business continuity plan for possible threats arising from climate change
	• Energy Supply	• To incorporate climate change-related risks and challenges in contingency planning
	• Food Resources	• To develop an emergency response management plan to deal with unforeseen food shortages
	• Human Health	• To periodically review warning, alert and monitoring systems, as well as emergency services and contingency plans
	• Water Resources	• To review drought contingency plans as desirable from time to time

4.7.4 Cross-sectoral Climate Change Adaptation Measures

In addition to sectoral level adaptation options, some cross-sectoral adaptation measures are proposed as follows:

- Climate change research activities – This could include the development of Hong Kong climate change projections (e.g. sea level rise, the marine environment changes and extreme weather events) to support further sector-level research on impacts and vulnerabilities.

- Education and public awareness – This could include the mass communication of climate change topics, in particular, the causes and potential impacts on ecosystems, climate variability and concepts such as risk and uncertainty so as to enhance the public understanding of vulnerabilities and the associated adaptation measures.

4.7.5 Coordination and Review of Institutional Arrangement

To ensure that institutional arrangements and Government departments are coordinating their climate change response and adaptation efforts, institutional arrangements need to be periodically reviewed and aligned as necessary to ensure co-ordination between different departments and that the Government is making decisions that is informed by the latest climate change science.

5 SUPPORTING ACTIVITIES

5.1 REVIEW OF CURRENT ACTIVITIES

A desktop review of Hong Kong's current research activities and other support programmes and plans in relation to climate change was undertaken and the following section summarises the key findings.

5.1.1 Policy Integration – Mitigation and Adaptation

One of the major Government initiatives to address climate change is the establishment of Interdepartmental Working Group on Climate Change (IWGCC), which consists of five bureaux and sixteen departments. The IWGCC is responsible for the coordination of the Government's work in response to climate change and is in charge of developing and promoting measures for the reduction of GHG emissions, as well as facilitation of adaptation to climate change.

5.1.2 Technology Transfer and Capacity Building

Technology is likely to play a central role in both reducing GHG emissions and adapting to climate change. The Government aims to promote Hong Kong as a knowledge-based economy by directly supporting high quality research, development and transfer of new technologies to various industrial sectors in Hong Kong. Together with the technology transfer arms of CUHK, CityU, HKUST and HKU there are at least six distinct organisations focused directly on technology transfer. Some focus areas of these organisations include: Research and Development (R&D), technological infrastructure, adoption of international standards and transfer of new technology to industry. The Government also has mechanisms and policies promoting cooperation between Hong Kong and the Mainland. For example, technology collaboration and development agreements have been signed between the HKSAR Government and the Mainland's Ministry of Science and Technology.

In terms of capacity building, the Government has provided funding for the Technology Development Branch (TDB) and the Environmental Management Division (EMD) of the Hong Kong Productivity Council (HKPC). They assist local enterprises to enhance productivity through technology transfer. The Vocational Training Council (VTC) is another institution that provides capacity building resources to raise the latent potential of Hong Kong's workforce.

5.1.3 Climate Change Research and Systematic Observations

Hong Kong's universities and the HKO have conducted research focused on a wide range of disciplines associated with climate change, including climate systems, environmental systems, the human environment and social science

based research. Research on climatic systems includes atmospheric, meteorological and oceanographic studies. There have also been a number of studies related to environmental systems such as ecological, terrestrial and hydrological studies. Studies on the human environment focusing on such topics as the built environment, human health and energy have also been undertaken.

In terms of the systematic observations and monitoring efforts, the HKO is the key government entity for meteorological data collation and analysis. In order to track weather information the HKO operates more than 70 Automated Weather Stations (AWS) and two manned weather stations distributed throughout Hong Kong. The key weather variables that are tracked include: oceanographic, surface, terrestrial and upper air observations.

5.1.4 Information on Education, Training and Public Awareness

The Government, non-government organisations (NGOs), universities and private sector have all contributed to raising levels of public awareness on climate change. Activities such as in the form of forums, public lectures, workshops, formal classroom training and media campaigns (including publications and internet campaigns) have been held in Hong Kong. A wide range of climate change related topics have been covered, including for example reducing energy consumption and the use of RE. These programmes focus on raising awareness amongst employees, business partners, and the general public regarding climate change impacts and the actions necessary to combat climate change. Local universities, the HKO and other organisations have provided technical training on several climate change related topics (e.g. climate modelling and carbon auditing).

Large scale public awareness campaigns conducted in Hong Kong include: the Government's "I Love Green, I Love Hong Kong"; WWF's "Climateer Ambassador's"; and HSBC's "Climate Change Partnership". In addition to general public awareness campaigns, some of Hong Kong's universities also offer specifically focused academic concentrations or courses on climate change (e.g. HKU's undergraduate minor in global climate change and HKUST's "Climate Change Risk, Mitigation and Adaptation").

5.1.5 Information and Networking

In accordance with the principles of "One Country, Two Systems" and the relevant provisions of the Basic Law, Hong Kong is eligible under the Clean Development Mechanism (CDM) . In addition, Hong Kong has also been active in establishing the foundations of cooperation on climate change through international agreements and organisation such as C40 Cities - Climate Leadership Group (C40) and Sydney APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development. The SAR has committed to tackling global climate change issues through strengthened economic cooperation, energy efficiency, environmental protection, scientific research and sustainable development.

5.2 *SUMMARY OF QUESTIONNAIRE SURVEY FINDINGS ON LOCAL RESEARCH ACTIVITIES*

Apart from the desktop review of local research activities under *Section 5.1*, ERM undertook a questionnaire survey with local universities, institutes, business organisations and NGOs to identify existing research activities, programmes and plans as well as core competencies and interests in areas related to climate change.

5.2.1 *Questionnaire Survey Process*

The online questionnaire survey forms were developed for two major groups of stakeholders, namely "Business and NGOs" and "Universities and Research Institutes". The survey was conducted between August 2009 and February 2010 and over 600 local stakeholders had been invited to provide responses to the online questionnaire survey. Also, to enhance the survey response rate, two rounds of email reminder and one round of phone call reminder had been made with the stakeholders during the survey period. 39 (including 26 business organisations and 13 NGOs) and 18 valid responses with verifiable contact information of the stakeholders were received from "Business and NGOs" and "Universities and Research Institutes" groups respectively. The following sections provide the summary of key survey findings. Whilst the questionnaire survey did not provide statistically significant responses from the stakeholders, it did gather their views and perceptions on climate change in Hong Kong.

5.2.2 *Business Organisations Group*

Although 72% of respondents indicated that have implemented or are planning initiatives/programmes that are concerned with climate change, of which 22% of this group indicated that >75% of their organisation's programme and activities are explicitly concerned with this topic. With regards to research activities, identification of technologies that facilitate mitigation is the most common research activity, followed by the policy research to facilitate adaptation. Some of these research programmes are carried out through collaboration with other local NGOs or local businesses including small and medium enterprises (SMEs). With regards to the technology transfer, most respondents indicated that such activities are carried out with overseas countries (including Mainland China and Macau) for mitigation technologies. For education, training and public awareness activities, they are typically carried out with primary or secondary schools or through housing exhibitions. In order to further promote and facilitate the development and implementation of climate change activities/programmes, most respondents commented that financial incentives are the most important factor for consideration.

5.2.3 *NGOs Group*

About 85% of respondents revealed that they have implemented or are planning initiatives/programmes that are concerned with climate change, of

which about 36% of this group indicated that >75% of their organisation's initiatives /programmes are explicitly concerned with climate change. These programmes mainly receive funding from donations or sponsors. With regards to the research activities, their key activities are those related to education and public awareness and promoting technologies to facilitate mitigation. Some of these activities are undertaken through collaboration with local tertiary education institutes. Unlike the Business Group's responses, most respondents indicated that their technology transfer activities are carried out with local transfer of mitigation technologies and these activities are carried out with local NGOs, local tertiary institutions or SMEs. With regards to the education, training and public awareness activities, these are carried out with primary or secondary schools or through public workshops and seminars. Similar to Business Group's responses, they consider that financial support is the most important factor to promote and facilitate the implementation of climate change initiatives/programmes.

5.2.4 Universities and Research Institutes Group

About 40% of the respondents indicated that their research activities are explicitly concerned with climate change, of which about 50% of these respondents indicated that they have been involved with climate change research in and/or systematic observations in the past 12 months. Most of the research activities are related to climate change impacts and vulnerability and human responses to climate change. Some of these research activities are carried out through collaboration with local or overseas tertiary institutes and it is funded by the University Grants Committee (UGC)/Research Grants Council (RGC) or other private funds. About half of the respondents indicated that they will have research activities and/or systematic observations that are explicitly concerned with climate change in the next 12 months and these activities will focus on systematic observations and human responses to climate change. With regards to the key factors required to promote and facilitate the development and implementation of climate change research programmes, most respondents considered that financial incentive is their most important concern, followed by the interest/demand from prospective students.

5.3 IDENTIFICATION OF ADDITIONAL SUPPORTING STRATEGIES AND MEASURES

Following the review of current activities, the following additional initiatives are recommended for consideration.

Research - Although research in Hong Kong is often of high quality, there is currently a limited focus on climate change related issues, technologies and impacts. There is a need for the development of localised emission factors and activity data so that GHG inventories can be more accurately calculated. More development in regional and local climate modelling is necessary to better predict the affects of climate change on Hong Kong. There is a need for additional research in a number of areas: oceanographic data (concerning sea level rise), biodiversity issues (e.g. terrestrial and aquatic species

composition, indigenous flora and fauna) and the potential affects on human health (e.g. the affects of climate change on disease outbreak or increased susceptibility). More Government and private funding should be directed towards climate change research to fill key data gaps.

Systematic Observations - The HKO currently conducts a number of weather observations, however, there are needs to enhance the long-term ecological monitoring efforts being undertaken by other Government departments such as Environmental Protection Department (EPD) and Agriculture, Fisheries and Conservation Department (AFCD). Hence, there is a need to regularly observe species composition, forests and biodiversity through additional terrestrial and aquatic monitoring.

Technology Transfer and Capacity Building – To further reduce GHG emissions, the Government should focus on technology transfer for climate change related applications and capacity building. The Government could encourage more Clean Development Mechanism (CDM) projects in Hong Kong and coordinate the promotion of transfer of climate change related technologies, such as electric vehicles and building energy efficiency technologies. The four Hong Kong Universities with technology transfer branches should also be given assistance in focusing technology development for GHG emissions reduction in key areas: the built environment, transport and the power sector. There is also a need to increase the number of people with professional qualifications and experience in carbon auditing, carbon footprinting and GHG inventory development and verification. Providing or subsidising the attainment of qualifications and certification (e.g. Certified Carbon Auditor Professional) in these areas should be considered.

Public Awareness – Many small and medium enterprises (SMEs) have been slow to implement GHG emission reduction, energy efficiency and climate change adaptation measures, hence there is a need for Government resources to encourage their participation. Industry seminar training that incorporates adaption of climate change contingency plans into their business models, comprehensive green business development strategies, supply chain management and green procurement should all be considered as potential topics. Also, there is a need to train experts in key climate change topics (e.g. vulnerability and adaptation). Inclusion of climate change topics in school curriculum (e.g. inclusion of climate change study as part of secondary school curriculum and study of global warming as part of undergraduate degrees) would raise the awareness levels amongst younger generation on climate change impacts.

Public awareness campaigns on a number of issues would also help in raising the level of awareness amongst Hong Kong's citizens and these include climate change science, current actions in Hong Kong to combat climate change, changes in individual's behaviour to reduce power consumption and waste generation, low-carbon/green business development and potential public savings garnered from adherence to energy efficient building codes. These issues should be presented through interactive media such as websites

as well as through the traditional media such as newspapers. Moreover, the Government could enhance the current efforts with various NGOs in organising these campaigns so as to raise the level of public engagement.

International/Regional Cooperation – Currently collaboration is limited to a small number of organisations and is lacking in areas such as energy efficiency and energy research, investment in green technologies and carbon markets. Many of Hong Kong's key resources providers (e.g. Thailand for rice) are at risk from climate change which has implications for the SAR. Increased participation (APEC economies) could also include specific actions to address climate related issues. Moreover, sharing of knowledge on oceanic changes and associated research into flood risk strategies should also be encouraged. For example, Hong Kong has joined the 'Connecting Delta Cities' initiative which is led by Rotterdam and includes other cities such as Shanghai, London, and New York, to share knowledge.

Policy Measures – This Study has presented a number of options which could be further developed for the HKSAR Government to create a comprehensive climate change strategy. See *Sections 3* and *4.7*.

Business Activities - As the extent of climate change impacts on businesses operating in or managed from Hong Kong is not well characterised, relatively few businesses have made it a focus of business planning or risk management. More funded research from the government and/or private sectors on potential impacts on businesses should be encouraged to address this information gap and to enable the private sector to make informed decisions for managing this source of business risk.

6 STAKEHOLDER ENGAGEMENT PROCESS

In order to provide an opportunity for public participation and to gather the views of a variety of stakeholders, ERM has applied various engagement approaches to inform the stakeholders about the study, its key findings and to invite their comments. These approaches include the establishment of a dedicated internet site for stakeholders and the conduct of a series of technical workshops.

6.1 DEDICATED STUDY WEBSITE FOR STAKEHOLDERS

ERM has established and maintained a project internet website (http://www.climatechange.com.hk/) throughout the study to facilitate communication with stakeholders. The website is open to everyone and has been used to provide information about the study objectives, workshop activities and to invite input/comments from interested sectors of the community via the dedicated email address (enquiry@climatechange.com.hk). Moreover, all materials from the workshops (see *Section 6.2*), including presentation materials, briefing papers and summary reports, have been posted on the website. As of November 2010, the website has been accessed by the general public more than 9,200 times since it was launched in early July 2008.

6.2 CONDUCT OF TECHNICAL WORKSHOPS

In order to inform the stakeholders on the study's progress and to gather their views/comments on the findings, ERM has conducted five public workshops. An overview of each of the workshops is provided in the following sections.

6.2.1 *Public Workshop on Climate Change Study*

A half-day public workshop was held at the Exhibition Hall of the Hong Kong Productivity Council on 18th July 2008. The purpose of the workshop was to present the aims and objectives of, and our approach to, the Study. Representatives of stakeholder groups including NGOs, academic institutions, business community bodies and professional associations were invited and over 70 attendees participated in the workshop. During the workshop an overview of climate change, the current state of the science, major global and local challenges, and a brief description of the approach to the Study and key tasks were presented. A record of the discussions and the views and queries of the attendees was made. Some of the key questions and comments raised by the stakeholders are summarised in *Box 6.1*.

Box 6.1 Selected Stakeholder Queries and Feedback

- How is the GHG emissions inventory of Hong Kong defined?
- How do the NGOs feed their own research findings or other information into this Study?
- Will this Study also focus on the poor communities in developing countries in adapting to climate impacts?
- If you just look at Hong Kong under this Study, losing a species in Hong Kong may be acceptable but not from the regional point of view. Therefore, this Study should have a more strategic vision and look at impacts to biodiversity in South China.
- This study will inform policy options. How much control does the Government have on this Study and what is the role of Government in this Study?
- Are you setting an emission reduction target and recommending a certain reduction measures? If you recommend certain measures, how do you do modelling studies to ensure that the targets are met?
- If the V&A assessment is not based on accurate information, I am worried that the relevancy and adequacy of the policy options recommended.

6.2.2 Mitigation Assessment Workshops

Two public workshops on the mitigation assessment were carried out during the Study period.

The first workshop was held on 25th September 2008 at the Main Conference Room of ERM's Hong Kong office. It was divided into four separate sessions, namely Buildings and Appliances, Power Supply, Transport and Waste and each session had about 20 attendees from various stakeholder groups. During the workshop, a review of existing policies and measures, both in Hong Kong and overseas, that help to reduce greenhouse gas emissions, as well as an overview of other initiatives aimed at mitigating emissions was presented. In addition, a list of policies and measures (e.g. mandatory implementation of carbon/energy audits in buildings, change of energy/fuel mix, congestion charging, and waste-to-energy facilities etc) that could potentially be implemented in Hong Kong was also discussed in order to seek technical input from the attendees, as well as to collect their views and comments. *Box 6.2* presents some of the views and comments from the stakeholders.

Box 6.2 Selected Stakeholder's Views and Comments

Building and Appliances

- Older buildings account for the majority of the building stock in Hong Kong, so targeting any energy efficiency performance improvements on this group of buildings could be expected to result in a bigger impact than a focus on constructing new carbon neutral buildings. Thus, it should be useful to have policy differentiation between new buildings and existing building to promote energy efficiency.
- Emissions associated with the use of air-conditioning and lighting are significant contributors. These areas deserve more attention as overseas experience suggests a potential energy saving of 20% in these areas.

Power Supply

- It was suggested that a greater share of gas and nuclear is desirable. Key concerns will be access to adequate gas supplies in the future and siting new nuclear capacity.
- Consumers need to be educated so that they are responsible for GHG emissions as well as the power companies.

Transport

- There are competing routes between buses and the MTR; measures could be taken to reduce multiple routes or combine some similar bus routes.
- The technology for electric vehicles exists and there is an opportunity for Hong Kong to develop the expertise and skills that can then be transferred to mainland China. There could be regional co-operation to produce electric vehicles and to promote their use. Hong Kong should considering creating the infrastructure for their use.

Waste Management

- Various comments were made about the need for more public information on the Waste-to-Energy (WtE) project and associated technologies in Hong Kong and the use of different terminology (i.e. gasification compared with incineration) to gain public acceptance of WtE.
- In general, it was acknowledged that, considerations for waste minimisation, waste management, waste strategy and implementation all originate from the waste problem in Hong Kong (not GHGs). Hence, if waste is well managed, the GHG emissions associated with the waste will be taken care of as well.

The second workshop was held on 30th September 2010 at the Main Conference Room of ERM's Hong Kong office. Two half-day workshop sessions were arranged and about 25 attendees participated in each session. The purpose of the workshop was to present the findings of the mitigation assessment and to gather the stakeholders views and feedback on these findings. *Box 6.3* presents some examples of queries and feedback from the stakeholders.

Box 6.3 Selected Stakeholder's Queries and Feedbacks

- What is the amount of GHG emission reduction achieved from demand side and fuel mix revamp respectively?
- What are processes and procedures involved in the import of nuclear energy into Hong Kong? Also, which parties would be involved in the decision making process?
- Offsetting the carbon emissions in Hong Kong should be carried out, rather than proposing actions and targets to combat climate change in the public consultation document.
- Will China's carbon intensity reduction target have any binding effect to the proposed Hong Kong target?
- What are the mitigation measures for domestic buildings?
- Is there any road map for the 10-year plan since the proposed regulation on Building Energy Codes (BEC) is still being discussed in the Legislative Council (LegCo) and the BEC is still currently a voluntary programme?
- The point-to-point supply of electricity to Hong Kong should be enforced to ensure that the electricity supplied to Hong Kong is generated from clean sources.
- How do we capture gas from landfill and produce energy? What is the efficiency of landfill gas capture? For waste water treatment, will gas be fully utilized? How about biogas from untreated water or those from illegal discharge?

6.2.3 Vulnerability and Adaptation Assessment Workshops

Two public workshops on vulnerability and adaptation assessment were held during the Study period.

The first workshop was held on 19th December 2008 at the Main Conference Room of ERM's Hong Kong office. Two half-day workshop sessions were arranged and over 20 attendees from various stakeholder groups participated in each session. The purpose of the workshop was to present the preliminary findings of the Study including the likely climate change impacts on Hong Kong, identification of key sectors most vulnerable to climate change, discussions on present-day adaptive capacity and constraints on adaptation, and potential adaptation options to be adopted in the future. The stakeholder's input and their views and feedback were also sought. *Box 6.4* presents some examples of the views and comments received.

Box 6.4 Selected Stakeholder Views and Comments

- There is very limited research on climate change related impacts of on biodiversity in Hong Kong. There could potentially be many impacts but it was felt that these currently rely on expert judgement. Hence, proposals for any specific adaptive measures would require more local research across different taxa as different species will respond differently to climate change. More information is needed in order to identify appropriate actions.
- Along with developing contingency plans, it would be necessary to factor in climate change to the architectural and engineering stages of new building development, as well as investing in research and development into building design and materials, such as passive ventilation and thermal mass.
- Gas supply in Hong Kong relies primarily on pipelines. There have been concerns over pipeline security so alternative delivery routes may need to be investigated.
- Many sectors are correlated and interconnected so it is difficult to isolate one sector from another. For instance, the financial services sector is highly interlinked with infrastructure, communications and the transport network.
- Hong Kong imports a significant quantity of food from Mainland China and the Pearl River Delta. Authorities from both sides need to cooperate and work together to examine the potential impacts induced by climate change.
- There are interlinkages between the Human Health sector and others. For instance, this sector is highly linked to the infrastructure people live in. Hence, building standards may help to improve housing design, natural ventilation and the maintenance of buildings, which in turn may help to improve living conditions for those who live in crowded conditions.
- At the moment, Hong Kong has a reliance on imports of water from Dongjiang. Greater flexibility needs to be incorporated into the contract terms so that the supply adheres to the demand in Hong Kong. Water quality needs to be maintained in the future.
- Adaptation to climate change should not be seen as a substitute for mitigation. Instead, mitigation and adaptation should be considered together.

The second workshop was held on 24th February 2010 at the Main Conference Room of ERM's Hong Kong office. Two half day workshop sessions were arranged and over 20 attendees from various stakeholder groups participated in each session. The aims of the workshop were to present the Study findings on vulnerability and adaptation assessment and seek the stakeholder's views and feedbacks on these findings. *Box 6.5* summarises some examples of the stakeholder's key views and comments.

Box 6.5 Stakeholder Views and Feedbacks

- Many aspects of marine aquaculture in Hong Kong are already very stressed due to environmental factors, and predictions that sea level rise will cause the collapse of various eco-systems have been made, e.g. mariculture done in very shallow water due to the already high mortality rates.
- Current building codes were often made on the assumption that weather conditions were static and unchanging, so the effect of extreme weather events is not reflected in current building code. It was recommended that climactic changes, historical and international data, especially for older buildings, be incorporated in adaptation measures for future versions, e.g. the influence of standards for the building envelope and debris input on sewage systems, floods, and transport.
- An increase in temperature would cause an increase in the demand for energy. Substantial increases in energy pricing would create a large burden on poorer groups of the population. A concern was raised that the issue here is not energy availability, but affordability. It might be necessary to create an energy policy assessing energy affordability for vulnerable groups.
- Due to limited operating life and a lack of long-term operating outlook, many small and medium sized businesses tend to not fully consider the effects of climate change.
- There is a need for a contingency plan should an interruption in the food supply occur or if prices rise significantly for basic foodstuff.
- There is a need for more government regulation and detailed plans regarding labour insurance and reaction plans to extreme weather.
- As the potential impacts associated with changes in average sea level carry enormous ramifications, it is important to consider the most accurate and up-to-date scientific findings when assessing responsive measures.
- To facilitate stakeholders' gauging how they would be affected and what adaptation actions should be considered and taken, information on vulnerabilities and adaptation strategies should be available to the public.

7 CONCLUSION

The Study has reviewed and updated Hong Kong's GHG inventories based on the latest methodologies in the *2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories.*

Hong Kong is moving along a path to a low carbon economy. The total primary energy consumption in the Base Case is projected to grow at an annual rate of 1.3% during the period 2005 to 2030, while the final energy demand is projected to grow at an annual rate of 1.8%. Compared to the projected 3.01% annual growth rate in GDP (1) over the same period, the decoupling trend between GDP and primary energy consumption implied in the annual growth rates is expected to continue. The annual growth rate of total carbon emissions, 0.24% per year between 2005 and 2030, is projected to decouple from primary energy growth. In comparison, the total carbon emission grew at an annual rate of 1.1% during the period 1990 to 2006 while GDP grew at an annual rate of 4.18%. The relatively low carbon emission growth rate projected is mainly due to the reduced utilisation of coal-fired power plant units by 2030.

To further mitigate Hong Kong's GHG emissions, our recommended approach will further reduce Hong Kong's carbon intensity by 54% to 60% by 2020 and, by 2030, will reduce carbon emissions per capita by approximately 50% and the total quantity of emissions by 40%, compared with the 2005 level. The cornerstones of this strategy will need:

(a) implementing mitigation measures

- transport - reducing the carbon footprint of road transportation through improving energy efficiency and the use of low carbon fuels, such as biodiesel derived from waste cooking oil;
- waste - maximising utilisation of landfill gas as a source of energy and building waste-to-energy facilities; and
- energy efficiency - widespread improvements in energy efficiency, in particular in the built environment and in electrical appliances.

(b) revamping the fuel-mix for electricity generation

- a significant increase in the proportion of low- or zero-carbon fuel such as natural gas and nuclear energy in the fuel mix for electricity generation.

Meeting the predicted levels of reduction in carbon intensity and GHG emissions under Scenario 3 by 2020 will require a significant and rapid rebalancing of the fuel mix in the electricity sector and associated investments

(1) The GDP projection and impact evaluated by the models is on the basis of real terms.

in the transmission infrastructure. Given the time needed to plan and construct such infrastructure, as well as securing energy supplies, early adoption of theses measures is required to ensure that the 2020 national policy target can be met. The cross-sectoral nature of this strategy and the speed with which it needs to be implemented requires support from all sectors of the community.

As climate change is a global phenomenon, the actions recommended to be taken in Hong Kong whilst substantially reducing GHG emissions, will not be sufficient to prevent climate change from occurring. In the coming decades Hong Kong can expect to experience increases in climatic instability. To address the risks presented by these changes, our assessment of vulnerabilities in Hong Kong has identified eight key sectors as having "high" vulnerability to climate change impacts, namely: Biodiversity and Nature Conservation; Built Environment and Infrastructure; Business and Industry; Energy Supply; Financial Services; Food Resources; Human Health, and Water Resources. To adapt to future climate change impacts, sectoral and cross-sectoral adaptation measures have been recommended for further consideration. This is the first comprehensive assessment of vulnerability to climate change in Hong Kong. It has been carried out based upon the current state of knowledge and the information available in the IPCC AR4 as well as consultant's and expert's judgments so as to make an assessment of the potential areas of greatest risk. It should be acknowledged that the quality and quantity of information available to make the assessment vary between systems. Moreover, there are uncertainties and limitations associated with the information in AR4 and hence the outcome of the vulnerability assessment. For instance, there is higher uncertainty in how biodiversity will respond to changing climatic conditions when compared to some other highly managed systems such as the built environment and infrastructure. Where there is a lack of local scientific data to support the research-driven approach to assess the vulnerability and adaptation of a particular sector, ERM has exercised expert judgement to determine the risk rankings, for example, the risk rankings under Human Health sector. With the rapid evolution in the climate change science, the vulnerability assessment should be considered as a dynamic process and the findings of the assessment should be regularly reviewed and updated, particularly given the high-levels of uncertainty inherent in an exercise of this nature.

As with other cities in the world, Hong Kong is vulnerable to climate change because of the agglomeration of people and assets in a small area. Hong Kong's vulnerability is compounded by its dependence on imported food, water, energy and other products that are required for it to thrive. Hong Kong possesses significant adaptive capacity and has many systems in place which could be used to adapt to the physical impacts of climate change. Nevertheless, a review of existing adaptation policies and measures adopted in Hong Kong as well as other world cities, including London, Singapore, Tokyo and New York City was performed to identify the following recommended frameworks for adapting to climate change:

- Sectoral-level actions in the eight most vulnerable sectors identified for Hong Kong.

- Cross-sectoral activities such as research activities to inform government decision making and activities to raise awareness of Hong Kong's vulnerabilities to climatic change, as well as possible adaptation actions to address them.

- Cross-departmental bodies to monitor and co-ordinate government action to ensure consistency across government decision-making.

Due to the limitation and uncertainty in the current assessment, it is recommended that the assessment of vulnerability to climate change is periodically reviewed and updated so as to take into account the latest scientific findings. Adaptation options should be reviewed in parallel to ensure that they remain adequate and take into consideration developments of climate change science and technologies.